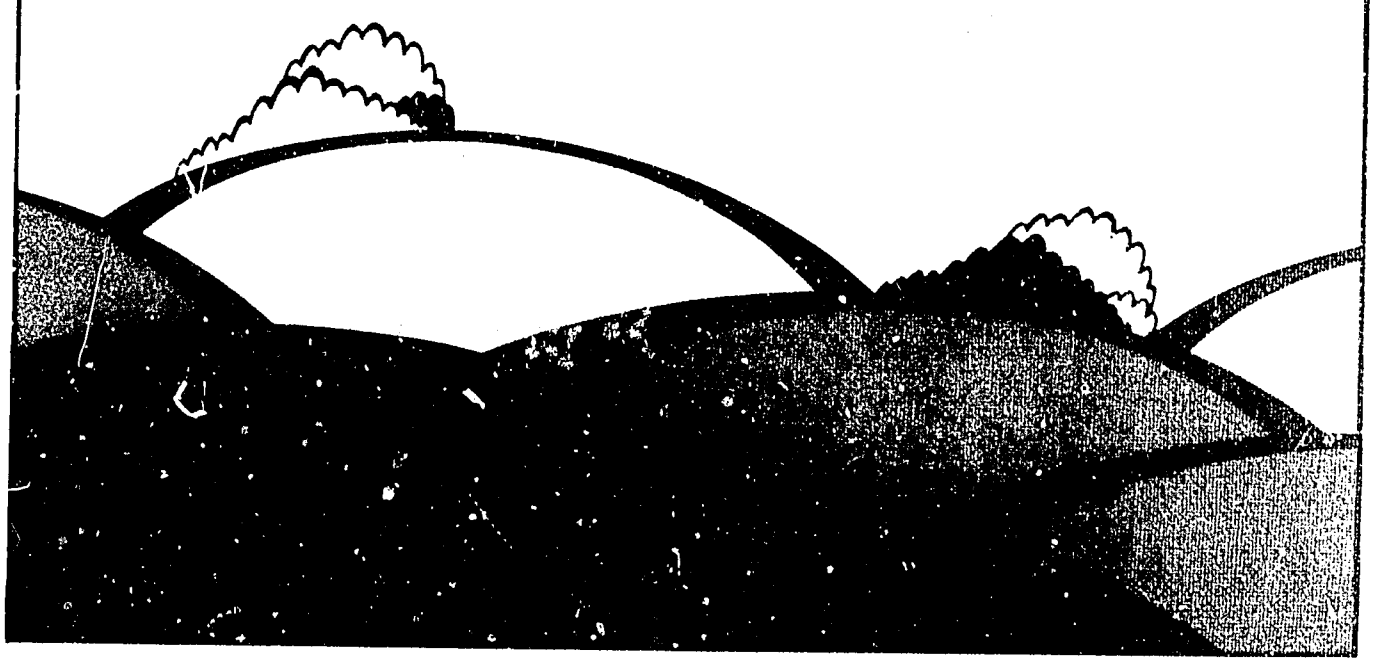
Hill Lands

Proceedings of an International Symposium

West Virginia University
Morgantown, WV, USA
October 3-9, 1976



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HILL LANDS

Proceedings of an International Symposium
held in Morgantown, West Virginia, USA
October 3-9, 1976

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Foreword

The original purpose of the Hill Land Symposium held in Morgantown, West Virginia, in October, 1976, was to consider means of increasing the agricultural use and productivity of hill land areas in the United States. Such a review seemed justified and timely in view of the dwindling prime land resources of this country and of the increasing need for animal production from pasture and forage crops. In recognition of the fact that a majority of the world's population living in mountain regions do so in developing countries (Asia, South America, Africa), and with the interest and support of the Agency for International Development, the scope of the conference was enlarged to consideration of the use of hill land for both crop and animal production in tropical and temperate regions of the world.

Emphasis throughout the conference was placed on the agricultural potential of hill country in contributing to the world's food needs. However, since increasing population pressures and changes in agricultural and industrial technology have been shown clearly to exert drastic effects on fragile mountain environments, sections of the conference were devoted to discussion of hill ecosystems, to use of hill country for purposes other than agriculture, to the impact of change on social and cultural relationships among mountain communities, and to the problems of effective reclamation of severely disturbed or eroded land.

The opening plenary session provides an overview of hill land use in different regions of the world. Thereafter, the conference is developed in eight different subject matter areas, with invited and contributed papers in each. Discussion of the papers was recorded, and much of this is included in the *Proceedings*, undoubtedly with certain of the errors and inequities to which such material is prone.

It was an intention of the conference to stimulate discussion of a common problem by people with a wide variety of interests and experience—administrators, scientists, advisory personnel, farmers and individuals with, simply, a strong concern for a vital part of man's natural environment. In an earlier colloquium in the United Kingdom, Watkin Williams (1973) concluded that in any discussion of hill agricultural problems, it is difficult to avoid developing either a sentimental or a brutal frame of mind. Such attitudes again will be reflected in the present *Proceedings*, and this is perhaps inevitable in taking a diversified approach to a highly complex problem. It is, however, the hope of the organizers of this conference that, from the broad canvas of interests and efforts portrayed, sufficient concern will be generated to encourage the development of further meetings of working groups or agencies with more specific objectives in utilizing and protecting the hill and mountain land resources of the world.

Editor's Note

The Hill Lands Symposium was a monumental undertaking. Next came the task of preparing the manuscripts for publication . . . the countless hours of editing, rewriting, retyping.

The Editor owes special thanks to the following:

My colleagues Jack Cawthon and Mike Breslin, for all their help in editing and proofing.

Miss Rhodagae Grimes, my secretary, for retyping many of the manuscripts.

Professors G. C. Anderson and R. L. Reid, WVU College of Agriculture and Forestry, for proofreading the first galleys and ironing out the fuzzy areas.

Mrs. Ruth Thomas, who kept track of all manuscripts and delivered them to me.

Paul Stevenson, chief WVU Graphic Artist, for his suggestions and advice on typography and design of the *Proceedings;* and Diane Lenhart, staff artist, for cleaning up the rough edges of (and, when necessary, redrawing) the charts and graphs.

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Acknowledgments

Early in the organization of this Symposium a generous grant from the United States Agency for International Development was received. This grant permitted enlargement of the scope of the Symposium program to make it truly international in character. Translation of the planned program into reality was made possible through additional financial support from the Claude Worthington Benedum Foundation, the West Virginia Department of Agriculture, the West Virginia Department of Commerce, the Agricultural Research Service of the United States Department of Agriculture, and West Virginia University. The West Virginia University Foundation, Inc. assumed responsibility for the financial affairs of the Symposium, and the organizers wish to thank L. L. Dudley, Director of the Foundation, for his advice and assistance.

Tours of hill land farms and of current coal surface mining and reclamation projects under the West Virginia Soil Conservation Service (USDA) were organized by B. S. Baker and M. Faucett, of the West Virginia University Allegheny Highlands Project, and F. W. Glover and D. Stanley of the Soil Conservation Service. The post-symposium tour of farms, research institutions, and historical sites in the northeastern region was arranged largely by John Baylor and G. A. Jung of the Pennsylvania Forage and Grassland Council, to whom the organizers and participants in the tour express thanks for hospitality and excellent organization.

It is not possible to acknowledge adequately the contribution of the faculty and graduate students of the Division of Animal and Veterinary Sciences and the Division of Plant Sciences at West Virginia University. Their willingness to serve wherever needed prevented many problems from becoming insoluble. Organization and use of audio-visual equipment contributed significantly to the success of the Symposium, and for this function the service and support of R. O. Thomas and T. Smith is especially recognized.

Finally, it is appropriate to mention the function of the West Virginia Forage and Grassland Council, which planned the conference and whose members worked hard to make it a success. The support of the parent organization, the American Forage and Grassland Council, in planning tours and activities is also gratefully acknowledged.

Throughout the development of the Symposium, the cheerful and competent work and interest of Mrs. Ruth Thomas has been invaluable. A special acknowledgment is due her for it is reasonably certain that she prevented chaos from becoming catastrophe on more than one occasion.

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Hill Lands

Proceedings of an
International
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Some abbreviations used in this volume

g	gram
ha	hectare
kg	kilogram
km	kilometer
l	liter
m	meter
mg	milligram
mm	millimeter
MT	metric ton
%	percentum

1.
Hills and Uplands in Britain—The Limitations and the Development of Potential

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Universally, the term "hills" implies adverse characteristics of physiography and remoteness, and climatic and soil constraints. The interaction of these factors confers a disadvantage on the whole hill farming economy. Uptake of technical advances from research and development by hill farming has been slow or nonexistent because of lack of investment capital, high input costs relative to low levels of response, small farm size, and labor shortage (Agr. Adj. Unit, 1970; Econ. Devel. Comm. for Agr., 1973; Jones, 1973; Smith, 1970).

In the U.K. there is often resistance to government investment in the development of hill farming because it supports only a sparse population and contributes such a small proportion of total agricultural output. One view is that since inputs give better return in the lowlands the hills are best consigned to nature conservation, recreation, and tourism. At the other extreme, inputs have been recommended on the basis of impressive improvements in herbage production, although with scant consideration of costs or systems (Williams, 1973). However, with the world's best agricultural land being depleted each year there are increasing arguments for devoting the best lands to primary crops to feed mankind and for hill country to have a much more important role in supplying man's need for livestock products, especially meat.

Whatever the current status of a country's hill land, it is important to keep options open and build up the technology needed for future development should this become expedient. This can only be done through a sound research and development program.

THE HILL LANDS OF EUROPE

The hill lands in northern and southern Europe lie in large contiguous masses, and there are marked contrasts between regions and much diversity within them. Problems in the north and northwest are different from those in the south and southeast where summers are warmer, soils less acid, no extensive peat deposits occur but population density in some areas gives rise to higher land pressures.

Hills and uplands have been defined as areas where the growth of plants for agricultural and pastoral production is depressed by climatic, soil, and topographic conditions. There is no standard relationship with height above sea level, and in the U.K., the cultivation of root crops and cereals ceases at much lower altitudes than in the rest of Europe. In parts of the west of Ireland and highlands of Scotland peat occurs at sea level, while in northeast England and the Welsh borders land up to 400 m is plowed. In some of the alpine regions of Europe cultivation is carried out up to 1 000 m where high radiation and the complex of valley bottoms and slopes allow a greater crop diversity, from maize to upper alpine pasture (Raeburn, 1969; Davies, 1968).

In general, the central massif of Europe enjoys much higher levels of production than those found in northwestern Europe where an extensive farming converts a very low level of vegetative production per unit area into a relatively unfinished livestock product. In central Europe, the farming is relatively less extensive, converting a higher level of vegetative production into a finished livestock product (Hunt, 1968).

Hill and Upland Farming in the United Kingdom

Hill sheep farming and upland rearing take up a third of the U.K.'s farm land—5.8 million ha of rough grazing, grassland and crops (Econ. Devel. Comm. for Agr., 1973). Unimproved native grassland accounts for 70% of this area. The precise physical demarcation of hills and uplands is impossible, and eligibility for grants under various hill farming and livestock rearing acts is based on the type of farming possible, officially described as follows:

> Land situated in an area consisting predominantly of mountains hills or heath and which is, or by improvement could be made, suitable for the use of breeding, rearing and maintenance of sheep or cattle but not, in the opinion of the appropriate Minister, for the carrying on, to any material extent, of dairy farming, the production to any material extent of fat sheep or cattle or the production of crops in quantity materially greater than that necessary to feed the number of sheep or cattle capable of being maintained on the land.

Such land occurs in Scotland, Wales, the Pennines and north of England, and the uplands of southwest England, and the Welsh Borders (Fig. 1). All hill farming systems are based on sheep, supplemented to various degrees by cattle; agriculturally there are no other opportunities. The saleable products are lambs, draft and cast ewes, wool, and weaned calves.

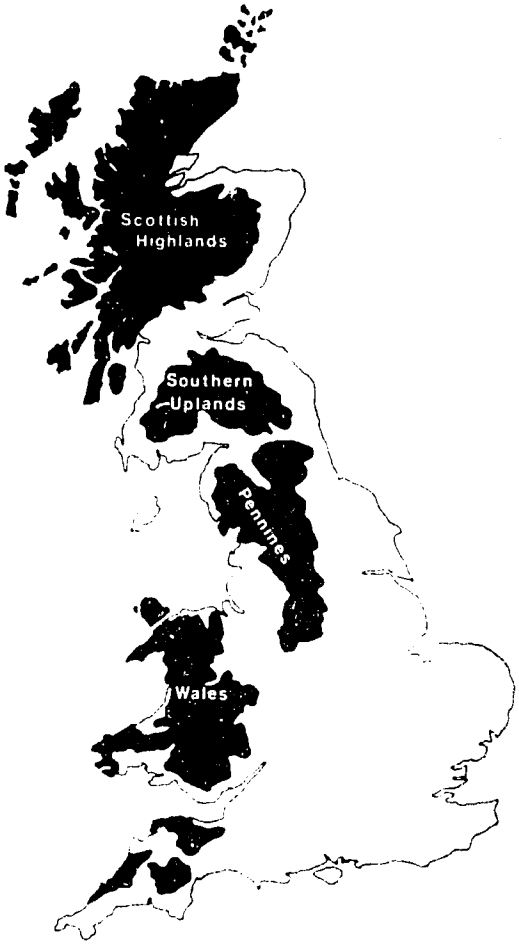

Figure 1. Hill and upland areas in Britain.

Output and profits are too low to provide capital for improvements and scope is often further reduced by limited areas of improveable inbye* land, lack of suitable buildings, and heavy reliance on common lands** which can lead to overstocking. Further, farms are very vulnerable to year-to-year changes in both prices and weather conditions (Jones, 1973; Agr. Adj. Unit, 1970; Smith, 1970).

Grants and subsidies have catered for land improvement, buildings and access. In the poorest areas only a small amount is claimed annually because farmers cannot raise the balance of capital needed (Smith, 1970). Headage payments are made on the hill cow and calf and on hill sheep. At times grants and subsidies amount to more than the net farm income (Jones, 1973).

Hill and upland farming in Scotland, Wales, and England contribute only 7% of total agricultural output, but make, nevertheless, valuable contributions to the livestock industry by contributing 50% of British sheep and wool production and 20–25% of the beef cattle output. The hills and uplands are the main source of store animals and hardy breeding stock for the lowlands (Econ. Devel. Comm. for Agr., 1973).

Hill farm systems in the U.K. are as varied as the economic and physical conditions which created them. At one extreme the hill sheep farms of the Scottish highlands can extend to over 1 000 ha but have little inbye land, very low stocking rates, little grazing control, very limited wintering land and marked under-utilization of pastures in summer. Three-quarters of all hill land in Scotland is stocked at less than one ewe/ha and one-fifth at less than an ewe/3 ha (Cunningham *et al.*, 1970).

At the other end, in southwest England and Wales, land is totally enclosed and the ratio of inbye to hill is seldom less than 1:15, and on the better farms it is 1:8. There is no recognized optimum, but when ratios are wider than 1:20 it is important to try to improve suitable adjacent land to augment the inbye acreage. In Wales, a large area of the natural vegetation has already been replaced by sown pastures. Little renovation has taken place, however, on the wetter lands at higher elevations (up to 600 m). Stocking rates are higher than elsewhere in the U.K., at 2.3 ewes/ha, and over-grazing in some areas has led to deterioration in pastures and reduction in sheep performance.

The upland sector, as distinguished from the hill sector, occupies the lower slopes on the better soil types in the lower rainfall zones, e.g., Welsh Borders and Pennines, and features cattle prominently. It comprises 60% of the total area of hill country but accounts for 85% of the total production (Econ. Devel. Comm. for Agr., 1973). Here, land improvement has already made a major impact and on some farms nearly all the rough grazing has been replaced since 1945, thereby creating a wider range of management opportunities.

CLIMATE, SOIL, AND VEGETATION

Since it is the sole source of ruminant feed for most of the year the nature of the native and improved vegetation is fundamental. It reflects soil, climate, and pastoral system, and therefore the environmental limits to production must be quantified. It is difficult to separate soil and climate effects, but reciprocal soil transfer studies have emphasized climatic factors as a major influence governing differences in grass production between hills and lowlands (Hughes, 1965; Lovett and Alcock, 1966; Alcock, Paper 80, herein).

Climate. In the U.K., cloud cover, rainfall, and wind velocity increase, and bright sunshine, total

* Enclosed land around the homestead.

** Unenclosed land held in joint occupation by a community and grazed in common.

radiation, evaporation and temperature range decrease with increasing altitude. Maximum temperature decreases more with height than average minimum. Even small changes in altitude over short distances cause rapid changes in the length of the growing season, growth rates and yields (Hughes and Munro, 1964, 1968). Compared with many continental countries, the changes with altitude in the U.K. are more rapid and varied. The decline in length of growing season varies from 4 days/30 m height in the northeast to about 10 days/30 m in the southwest. In Switzerland, the 2 days/30 m change suggests the same length of growing season at 600 m above sea level as the U.K. has at 300 m or less.

Farming is particularly affected by the length of the winter, the considerable temperature restraint on spring grass production, and high rainfall in mid-summer which causes extreme variation in the quantity and quality of hay. Marked differences occur from year to year, including winters severe enough to cause sheep losses and to drastically reduce subsequent pasture yields. In mid Wales, intensively managed *Lolium perenne* swards can reliably produce 15 MT/ha in the lowlands and 10 MT/ha at 300 m in a favorable season, but winter damage and low spring temperatures can reduce the latter yield to 4 MT/ha in three years out of ten (Munro, 1974).

There are many problems concerned with studying crop-weather responses and site potential in hill areas. Complexes of slope and aspect affect radiation, temperature, and evaporation, while barrier and channelling effects on wind create further complications. It is essential, therefore, to take meteorological data on the actual site, though there are pitfalls in relying entirely on physical data and on derived measurements such as potential transpiration. Estimates of the onset of spring growth from such data showed a three-week difference between 30 and 330 m elevation. In terms of grasses overwintered on these sites the difference may be six weeks (Hughes and Munro, 1964, 1968).

Climographs are a useful way to present pictorial comparisons of the temperature/rainfall patterns in different countries and within countries such as the U.K. where small differences may sharply differentiate the biotic potential of two nearby areas. Polygons produced by plotting monthly temperature against rainfall, and joining the points in sequence are presented in Fig. 2 to illustrate variation within Britain and comparisons with central Europe.

The need for more direct measurements of the climates that typify hill country has been emphasized (Raeburn, 1969). Ecological and land use maps are useful guides, and in conducting a soil/vegetation survey for Scotland the Macaulay Institute found it desirable to characterize the climates of sites, mapped on a scale of 1:625,000 (Birse and Dry, 1970; Birse and Robertson, 1970; Birse, 1971). Three maps were produced, one based on accumulated temperatures and potential water deficit, and the second on exposure and frost; the third map defined the regions on the basis of a scheme of bioclimatic sub-regions. This approach is strictly geographical but forms a good basis to extend to more direct agricultural usage.

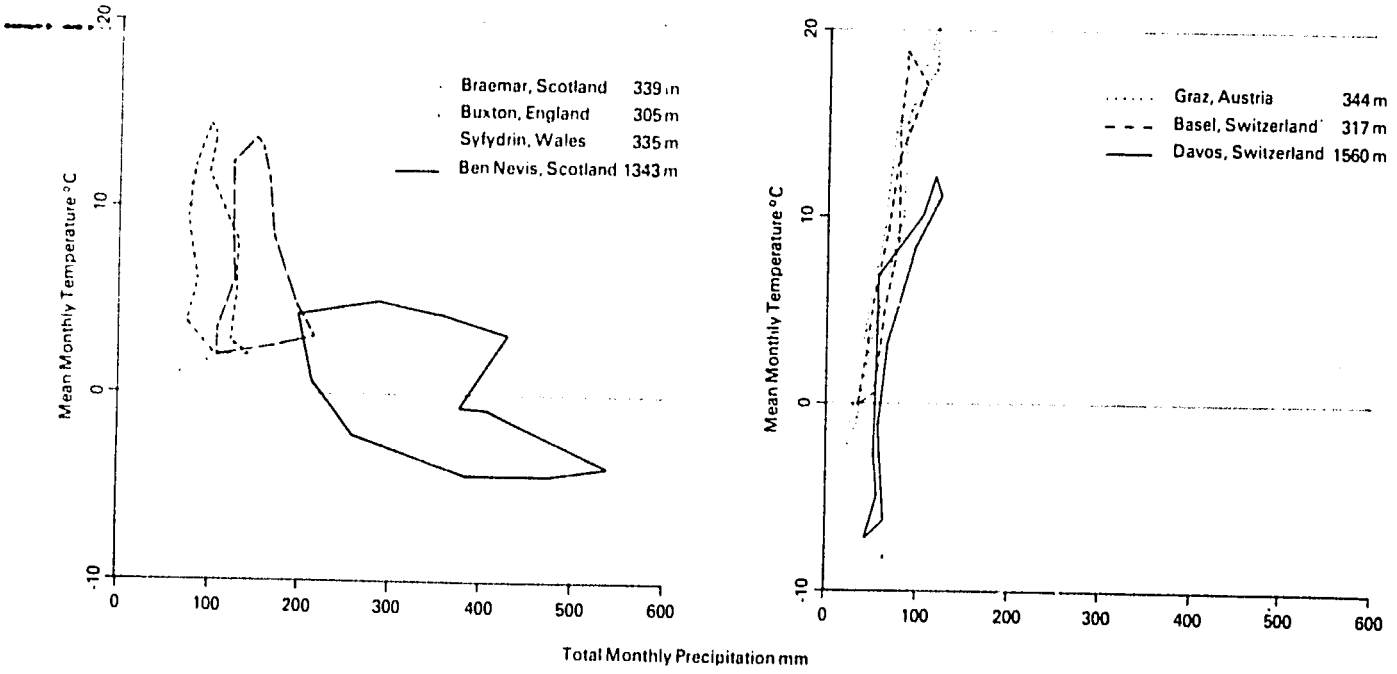

Figure 2. Temperature-Rainfall Climographs.

Soil. The uplands and highlands in the U.K. are dominated by Palaeozoic rocks, characteristically harder sedimentary, crystalline igneous and metamorphic types resistant to weathering (Pearsall, 1968). There is a natural decline of fertility with altitude, soils being typically shallow, stony, and poor in structure, with low nutrient status often exacerbated by excessive leaching and waterlogging. Extreme acidity is often encountered (pH below 4.0), rate of organic matter decomposition and humification is retarded, and acute deficiencies of calcium, phosphate and, above all, of available nitrogen, are common soil features. Poorly drained gley soils in valley bottoms often have high contents of exchangeable aluminum.

Ground drainage conditions vary markedly over small distances, giving complex soil distribution patterns with marked gradients in pH, redox potential, loss on ignition, silt content, C/N ratio, base saturation and cation exchange capacity (Munro *et al.*, 1973). Five main groups of soil are usually distinguished—skeletal, peat, podzols, gleys, and brown earths (Crompton, 1958).

In defining the soil limitations to potential pasture improvement Munro and co-workers (1973) have emphasized the major role of soil in the success or failure of sown pastures. In comparing soil nutrient resources stress is placed on apparent density, which can vary 6-fold between deep peat and mineral soils. In particular, lime requirement is greatly influenced by bulk density, and serious over-liming of deep peats could occur, leading to induced potash deficiency (Munro *et al.*, 1973).

A major limitation is the low level of available nitrogen. During 1967–70 the actual N uptake of a sown perennial ryegrass pasture ranged from 1.5 kg/ha/annum on a peaty gley to 66 kg/ha on a more fertile, free-draining brown earth. This contrasts with the 150 kg released by intensively managed lowland soils under paddock grazing (Munro, 1974).

Table 1 illustrates typical soil nutrient concentrations; it highlights the poverty of hill soils.

Vegetation. The pattern of spacial distribution and inherent productivity of the main vegetation types is closely linked with soil environments, especially pH and drainage, and with grazing pressure. The best indigenous pastures are associated with greater soil base status and grazing pressure, and are dominated by *Agrostis* and *Festuca* species. *Pteridium* fern is a problem when it dominates the grass component on such mineral soils. At the other extreme, ubiquitous blanket bog supports only very poor quality *Calluna—Eriophorum—Trichophorum—Sphagnum* vegetation. Including heaths, *Calluna* is a major component of Scottish rough grazing, covering some 1.5 m/ha. On more acid soils in Wales grazing pressures are high enough to eliminate heather but not to prevent the relatively unpalatable *Nardus* and *Molinia* dominating in its place on peaty-gleys and peaty-gleyed-podzols.

TABLE 1. MINERAL CONTENT OF SOILS (After Hughes and Munro, 1968)

Soil	Kg nutrient/ha								
	Ca	Mg	K	Na	P	N	Al	Mn	Cu
Hill mineral	94	65	320	43	4	235	623	115	0.73
Hill peaty gley	74	48	119	43	7	87	692	10	0.21
Lowland mineral	2690	157	179	95	13	—	—	—	—

Yield potentials are not easy to assess and estimates have varied considerably, but a rough datum point would be as follows (Eadie, 1973):

Agrostis-Festuca	2–3 MT/ha/year
Molinia-Nardus	1–2 MT/ha/year
Edible-Calluna	1–3 MT/ha/year

A good lowland pasture containing white clover in a high rainfall area would produce 3.5 to 6.5 MT/ha without nitrogenous fertilizer.

Feed quality for the species in the above list is very poor, digestible energy, protein and mineral concentration of standing crops of herbage being generally well below animal maintenance requirements (Munro, 1974). DOMD levels (digestible organic matter expressed as a % of dry matter) are illustrated below:

	June	August	December
Agrostis-Festuca	56	44	41
Nardus	48	50	35
Molinia-Trichophorum	42	45	26

The growing season is short, and under the year-long, free-range, set-stocked pastoral system, sheep have to graze very selectively to obtain a reasonably digestible feed. Despite low stocking rates the degree of selection opportunity is inadequate at certain times to satisfy nutritional demands. At worse, where hard winters and low summer stocking rates prevail, as in Scotland, a vicious circle is created in which the quality of the standing crop of herbage is diluted by the build-up and carry-over of rejected herbage. At best, utilization efficiencies are 30%. Improving the animal nutrition cycle by greater grazing control is an important objective, but sheep nutritionists have not always been attracted by the potential contribution of improved pastures. By the same token, pasture improvers have been mainly interested in the techniques themselves and less concerned with whole farm management systems that could benefit from the improvement (Agr. Adj. Unit, 1970; Eadie and Black, 1968).

THE DEVELOPMENT OF POTENTIAL

Current Production. Regional differences in system and in husbandry practices reflect quality of land and opportunity. On the poorest farms, e.g., western Scotland, rates of lamb growth (10–15 kg/ha per year) are less than half the 30 kg/ha found on the more heavily stocked, more favored Welsh farms.

The comparison with the lowlands is even more telling (Eadie, 1973). On the hills, stocking rates of 0.8 ewes/ha, 80% lambs weaned and lamb liveweights of 24 kg, are associated with 2000 kg/ha of pasture production, giving 15.3 kg/ha of weaned lambs per annum. This compares with 600 kg in the lowlands. According to Eadie (1973), this 40-fold difference of lamb output is a function not only of a 5-fold difference in herbage production, but also a 3.5-fold difference in the efficiency of utilizing the pasture and a 2.25-fold difference in conversion efficiency by the lamb.

Against the background of low output relative to costs, the only opportunity for increasing output lies in technical improvement, particularly to create an overall increase in the plane of animal nutrition, the key for which lies in pasture improvement. The main trend has been to remain static and rely heavily on subsidies. Some farm amalgamation has increased the size of the land management unit, and a limited use has been made of low cost methods on hill sheep farms. In Wales, mainly on the upland, and on drier slopes of the better hill farms, great use has been made of various government incentives. Since 1952, over 0.1 million ha of pasture have been improved, largely by plowing and reseeding. This, and the use of root crops, has led to higher stocking rates, more lambs reared per ewe, reduced ewe mortality, heavier lambs at weaning, and heavier fleeces. Many such farmers not only supply breeding ewes and store lambs for the lowland fat lamb market, but also have entered the fat lamb market themselves. Similar improvements in cattle output have resulted and it is possible to maintain a higher cattle:sheep ratio. As a direct result, hill-ewe numbers in Wales have increased by 87% and hill cows by 235% (Munro, 1974).

The hills of Britain are not amenable to vast and rapid change. Plowing or rotating large areas can lead to undergrazing, drainage problems and *Juncus* invasion, and ultimate deterioration. The issue of the common lands has to be considered since 80% of the 0.6 million ha is grazing land, and little positive advance has been made in its use, even where soil and other factors present ideal opportunities for development.

When considering land improvement, therefore, the fundamental considerations are the potential of the land and how much to spend on it (Smith, 1970).

PASTURE IMPROVEMENT

Elucidation of Potential. It has already been emphasized that the soil, climate, and vegetation limits have to be quantified and related to productivity (Munro and Davies, 1973; Alcock, Paper 80, herein). The scope for improving total and seasonal dry matter production and the feed quality of the standing crop by grazing control leading to better utilization must be elucidated. Marked increase in production, however, needs fertilizer inputs and, possibly, reseeding, and the potential production at different levels of fertilizer input gives a more complete picture (Davies and Munro, 1974).

The potential varies with the soil, native vegetation, and site. Results for a *Molinia/Nardus* area on a peaty-gley are shown in Table 2.

TABLE 2. Annual yield of dry matter in kg/ha and feed quality of herbage from swards 10 years after different treatments applied to *Molinia/Nardus*

(Davies, D. A., Welsh Plant Breeding Station, unpublished)

Sward treatment		Yield	% DOMD	% CP	% WSC
Original herbage		1 120	37	7.1	3.6
Controlled grazing		2 290	49	15.6	8.9
Lime and basic slag		2 520	58	14.6	11.0
Lime, basic slag and 50 kg N/ha		3 410	66	17.3	12.7
Lime, basic slag and 250 kg N/ha		4 871	73	24.8	12.0
Dalapon	Complete	4 940	73	18.6	14.3
Forage harvester	fertilizer and	5 570	73	18.8	14.2
Rotavation	seed mixture	6 300	72	17.0	16.1
Plow and Reseed Complete Fertilizer					
S. 23 *L. perenne*	50 kg N/ha	6 120	75	18.0	16.7
S. 59 *Fest. rubra*		6 300	70	21.4	13.5
S. 23	250 kg N/ha	10 190	72	18.9	13.1
S. 59		6 950	75	24.4	11.5

All treatments control grazed rotationally.
Stocking rate adjusted according to herbage on offer.
Data based on six sampling periods.

Techniques. (See Paper 12, herein, for more detailed discussion of techniques.) The basic techniques for bringing about marked changes in the state and botanical composition of hill swards and for reseeding a whole range of hill soils were recorded 40 to 50 years ago (Hughes, 1970). In the U.K. the cornerstone of hill land improvement has been the introduction and survival of *Trifolium repens*. The main cause of sward deterioration after treatment is poor drainage, followed by inadequate fertilizer maintenance dressings and lack of grazing control. Plowing wet land has led to such an invasion of *Juncus* species that the sward can be poorer than in its original state.

Improvement Strategy. The basic strategy for further improvement in Wales is to intensify production on the cultivated and inbye areas. In order to improve the yield and quality of herbage conserved for winter feed it is necessary to relieve stock pressure. It is essential, therefore, to improve the feed value of the surrounding wetter grasslands by surface treatment techniques. Studies on both problems are in progress at the Welsh Plant Breeding Station. For example, (1) a whole new series of bred grass and legume varieties are being evaluated and production potential elucidated for different levels of fertilizer input. Emphasis is given to feed quality characteristics of hay and silage crops and the lamb-fattening potential of aftermath growths; (2) by seeding different proportions of a wet *Molinia/Nardus/Trichophorum* area the following improvement in annual livestock output was achieved:

Control, 2.4 ewes/ha	35 kg live wt. gain/ha
20% improved, 5.6 ewes/ha	91 kg live wt. gain/ha
40% improved, 9.8 ewes/ha	153 kg live wt. gain/ha

The figures are means of the five years 1972–76.

The Ministry of Agriculture started a large-scale development project in 1971 on a mountain area of 840 ha lying between 485 and 565 m at the Experimental Husbandry Farm in mid-Wales. The principles involved are: (1) identify the feasible areas and consider the best techniques to apply to the plant communities present, (2) ascertain which areas should be, if at all possible, enclosed, (3) assess the need for access for the transport of lime and fertilizers, (4) estimate the costs of roads, and (5) estimate the capital needed to finance the program and to purchase stock.

A survey revealed 200 ha of improvable land, 470 ha of useful sheep grazing land, and 170 ha of little agricultural value (*Eriophorum* bog). Much of the cost of improvement, fences, and access roads was met by the sale of 170 ha for afforestation. The effect of livestock output and on returns is being monitored over several years (Roberts, 1973).

In Ireland a country-wide estimate of the developmental potential of land for agriculture was made (Lee and Diamond, 1972). Potential levels of animal production were related to soil type and then to present levels and to recent trends in the livestock population. The extrapolation of animal production experimental data to the country at large was then possible. Targets in terms of livestock units per 40 ha at two levels of nitrogen inputs were derived for each soil type.

In Scotland, the Hill Farming Research Organization in studying input/output situations and complete animal production systems both on the ground and by means of modeling techniques (see Papers 54, 118, 136, and 42, herein). The greatest success is achieved where a land improvement program is based on a concrete livestock policy for the individual farm. Having decided production targets, the degree, type and extent of land improvement necessary to meet the livestock demands must be determined. The facilities and skills available to apply the management system necessary are vital considerations, since any substantial improvement in grassland, stock-carrying capacity, and livestock quality has to be linked to high management standards.

Research is still required on specific components, but development must be considered on the basis of the complete hill farming system.

LAND USE

The object of any multiple land use strategy is to make the best use of physical and economic resources for the betterment of local and national well-being, serving both the prevailing economic and social needs. In Wales there is particular emphasis on curtailing or even reversing the drift of young people away from the marginal lands (Welsh Council, 1969). For most hill country, the basis of such a strategy is a viable, efficient agriculture. The need for a rationale with forestry, recreation, water storage, and tourism is as well recognized as the need to balance the loss of good quality land to industry and roads (50000 ha per annum) by improved agricultural production from underdeveloped land (Econ. Devel. Comm. for Agr., 1973).

While technically a very high proportion of hill land can be improved, economically some areas being currently farmed cannot be improved and these should be identified. Large tracts of wet moorland, dominated by species of the lowest agricultural value, with less than 1% of suitably sited cultivable land, and wintering ground a long distance away, would seem to have no future (Agr. Adj. Unit, 1970; Hughes, 1970).

There is still a need for reconnaissance and air surveys to enhance knowledge of the distribution of vegetation and soil types and improvement in land classification categories. National decisions on land utilization could be better founded, and direct competition between forestry and sheep farming could be avoided by careful siting based on land capability assessment. Maximum benefits can be derived by giving up selected areas to forestry and the provision of access roads enabling surrounding land to be improved to a state where an increased livestock holding can be maintained (Roberts, 1973).

Again, at farm unit level, basic map information and data from detailed studies of physical and biological limitations and estimated improvement potential will allow farm ecograms to be constructed on the basis of the soil/vegetation mosaic.

The Future

It has been suggested (Econ. Devel. Comm. for Agr., 1973) that there is a need for a special government study to collect and analyze data to identify conditions under which it would be of continuing economic value to the nation to encourage cattle and sheep production in the hills and uplands of the U.K. The latter appear to have a reasonably attractive future in the context of the European Economic Community (EEC). Farm incomes increased in the early 1970s, only to suffer a recent set back due to escalating costs. Given the positive approach in the "less favored area" directive (EEC) and a further improvement in cooperation between farmers in the hills, uplands and lowlands, the availability of technical developments, thanks to a sound research and development program, could lead to prosperity in British hill farming. Government policy favors an expansion in the grass/livestock industry (Command Paper, 1975), and the hills and uplands must be charged with making a major contribution.

The main requirement is not for more basic research but for an economic and management framework (Williams, 1973) that will generate confidence in the application of technological improvements.

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DISCUSSION

Unidentified. You mentioned that fertility rapidly deteriorates with altitude. Now I presume that this applies to well-managed land. What are the factors responsible for this relationship?

Hughes. I was referring to all land; soil fertility decreases because of poor parent materials and high rainfall leading to high leaching. The result is poor structure, poor nutrient concentration, and often a high content of organic matter.

Bob Chaplin (Mississippi, USA). In looking at your slides I noticed that there were a few small woodlots and in your closing remarks you mentioned forestry. What are the economic differences in production per ha for forestry compared to grasslands?

Hughes. The woodlots on the slides were shelter belts. I am not qualified to compare the economics of forestry and hill farming. Those that are cannot always agree on the system of accounting, but all agree that interest rates are an essential consideration. Bearing in mind that most of the land I discussed is suitable only for the production of soft wood for paper pulp, the return per ha would be heavily in favor of sheep production on farms with a planned land improvement program.

R. E. Blaser (Virginia, USA). I was very surprised at your report that nitrogen fertilization deters winter survival. Indeed, we find the reverse even at very low temperatures with lolium, peas, and many species simply based on the very sound principle that respiration, that is, cell division and expansion, is very low during cool periods, whereas photosynthesis is very high so soluble carbohydrates continue to build even with autumn and winter N fertilization. This autumn and winter N fertilization is the backbone of the turf program and in forages it's an excellent procedure to accumulate forage in situ. On the other hand we encounter winter kill in the summer by using too much N, especially in the spring season. I was wondering what principle is involved when you get winter kill, since at temperatures much lower than yours, we don't.

Hughes. The principle is based on the particular light regime you have during crucial periods. In our autumn and winter, light is a major limiting factor—a mere 70 cal/cm^2/day. To evaluate the wintering ability of grass breeders' populations we apply heavy nitrogen and allow growth to accumulate. Following defoliation in the autumn when these grasses expand their leaf surface then they're virtually using all the photosynthates to do so and there is nothing going down as reserves. This is very largely why we do have this relationship between high N input and winter kill, despite the fact that our winter temperatures are higher than yours.

Gus R. Douglass (West Virginia, USA). I note in your discussion that you made no mention of chemical weed control or use of herbicides to control unwanted species. I wondered what your thoughts were in reference to this?

Hughes. The only place for herbicides on our hill farms is as a pre-treatment prior to upgrading the botanical composition and feed quality of native vegetation. Their use will be discussed in Newbould's paper later in the conference. If you want to invest in such an input, the crucial feature is whether any increase in output is sufficient to justify it. In those terms using chemicals to control sward composition after *sward* improvement is a very doubtful proposition.

2.
Situation and Trends of Hill Land Management in Central Europe

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Demarcation of Hill Land

The hill land regions in Central Europe mainly consist of the German and the French hills and the Alps, which politically belong to France, Switzerland, Italy, Germany, Austria, and Yugoslavia. Looking at Europe as a whole from the North Cape to Sicily, these mountain regions are located in the southern part of Central Europe.

The demarcation of hill land in the different countries is not standardized. According to a law dated 23.6.61 the French hill lands include communities which have more than 80% of their area above 600 m above sea level or which have differences of not less than 400 m between the highest and the lowest point of cultivated area. Neighboring

communities under similar conditions can be exceptionally acknowledged as hill land even if they do not completely fulfill the requirements. So, in 1962, 4 263 communities were acknowledged as hill land communities, 1 165 of which were in the alpine region (Rintelen *et al.*, 1973).

Italy has similar regulations; 80% of the community area must be above 600 m above sea level, but the difference in altitude must be at least 600 m. Exceptions are possible as in France. So 3 971 communities belong to the hill land region, roughly half of them located in the Alps and northern Italy (Rintelen *et al.*, 1973).

In the Federal Republic of Germany an altitude of at least 500 m above sea level and a slope of more than 25% are required. In addition, extreme conditions for climate, soil, marketing and traffic are also considered. So 156 communities belong to the hill lands in Bavaria (Rintelen *et al.*, 1973).

The alpine regions are only of minor economic importance for Germany, France, Italy and Yugoslavia. For Austria and Switzerland, however, they represent the central region of the state. Compared to France this is demonstrated by the following figures (Table 1).

TABLE 1. Percentage of hill land area and corresponding population in France, Switzerland, and Austria

	Hill Land	
Country	% of Total Area	% of Population
France	4.8	2.1
Switzerland	58.5	14.9
Austria	66.0	32.0

(Lohr, 1971)

Situation of Hill Land Management

Although the economic and structural differences among the hill regions in Central Europe are extremely large, one can say that in the past they have been utilized agriculturally as much as possible and necessary. Especially during periods of crises and wars, areas with lower productivity were also utilized. After World War II the economy of the countries mentioned went through a boom, which showed different rates of increase, but also offered possibilities of income outside agriculture to a larger extent than before. The salary thus obtained was soon used as a guideline for further land utilization.

At the same time workers steadily left the farms, the costs increased and plant and animal production was intensified by means of chemistry, technology and engineering to an extent never observed before. This trend to increased agricultural yields could not be followed for a long time by most of the farms in the mountain regions. Extreme slopes and altitudes, small farm units and splitting of ownership limited the use of labor-saving machines; especially low production potential inhibited sufficient financing of production increasing means because of rough climate and poor soils. The changes in profit of hill farms compared to low plain farms with high yielding conditions from 1959–62 to 1966–69 in the Federal Republic of Germany are demonstrated in Table 2 (Rintelen *et al.*, 1973).

The same conclusions can be made from French investigations. Comparing the mountain region of Beaufortin with three low land areas, the results, demonstrated in Table 3, were obtained.

Only the following criteria showed better results for the hill land farms: fertilizer costs per ha agricultural area (a.a.), costs for bought-in feedstuffs, indirect costs and charges on real estate per ha agricultural area.

Because of the decreasing profits many farms in the hill lands have already been given up. In most cases these were smaller farms. They had been utilized as part-time farms from the beginning, or the owners had no chance for subsidiary earnings and therefore had to look for jobs farther away, so that part-time farming was not possible anymore. The abandoned areas became fallow land. Only to

TABLE 2. Reduction in profit of hill farms compared to low plain farms with high-yielding conditions (=100) from 1959–62 to 1966–69 (Rintelen *et al.*, 1973)

Average in the Years	Agricultural Area			Arithm. Means
	Up to 20 ha	20–50 ha	Above 50 ha	
1959–62	70.4	77.5	59.2	69.0
1966–69	59.2	71.9	57.8	63.0
Reduction	−11.2	−5.6	−1.4	−6.0

TABLE 3. Comparison of hill farms with farms in three plain areas in Savoyen (Veyret, 1973)

Criterion	Relative Performance in Hill Land (Plain = 100)
Average milk yield/cow/year	81–95
Gross output per ha agricultural area	59–75
Milking cows per laborer	65–90
Milk yield, kg/laborer	62–74
Gross output/laborer	54–71
Agricultural income/ha a.a.	72–88
Income/laborer	56–79
Working capital/ha a.a.	67–75

a small extent were they utilized by neighboring farms because manifold difficulties which varied from region to region opposed independent formation of larger farm units. The fact that fallow lands are first found in smaller farms has been demonstrated by Würfl (1976) in the Rhön hills (Fig. 1).

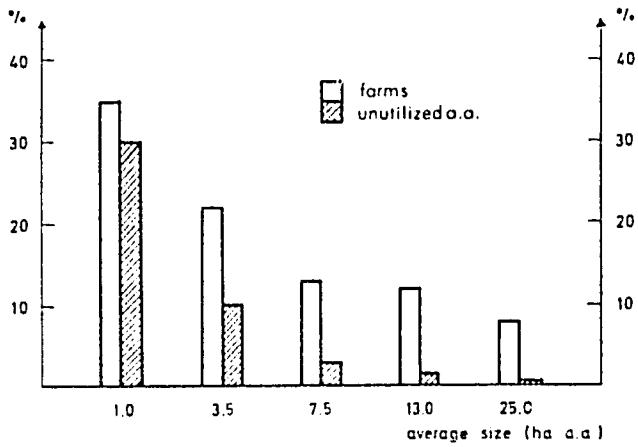


Figure 1. Number of farms with unutilized agricultural area (a.a.) and the percentage of total a.a. in different farm-size categories in the Rhon hills (Wurfl, 1976).

It is hardly possible to foresee the extent of those areas which in the future will not be used agriculturally anymore because of the unpredictable political and economic impulses. In the Federal Republic of Germany for instance this has meant 300 000 ha since 1945 or 2.2% of the total a.a. Up till 1980, Menzinger (1974) expects an extension of fallow land up to 500 000 ha, that is 3.7% of a.a., whereas up to 1985 one expects 1.5 million ha, that is, 11.2% of a.a. However, fallow land is not only located in the hill areas, but also to a considerable extent in the plain with unsuitable farm structure, on poor soil difficult to cultivate and with suitable income possibilities outside agriculture. Basically, one can differentiate three kinds of fallow land with specific causes for development, according to Steinhauser (1974b):

1. *Social Fallow:* Areas which could be used agriculturally because of their natural conditions but the owners of which make money outside farming to improve their social and economic situation.

2. *Structural Fallow:* Areas with suitable natural conditions abandoned by existing farms because size and location do not permit a profitable agricultural utilization and because structural deficiencies cannot be eliminated except with relatively high input.

3. *Marginal Soil Fallow:* Areas with unsuitable natural conditions, where agricultural utilization under the present price-cost-relations is not profitable anymore.

In the hill lands almost exclusively marginal soil fallow can be found. On the further management of these areas only general proposals exist. What kinds of demands are postulated by ecology, landscape and tourism in respect of utilization and management of fallow land in every single case can only be determined by investigation of the function of single parts of the landscape and by a planning concept for the total region.

Future Trends

For utilization only three alternatives exist: (1) natural development without any substantial activities by man (guided succession); (2) afforestation; (3) extensive landscape utilization and cultivation (to keep the landscape open).

The natural development of vegetation on different types of fallow land is in some cases permissible (Bauer *et al.*, 1975), however, in most cases a certain amount of cultivation is necessary. For instance, mowing of dry meadows every fifth year to prevent the regrowth of forest, or extensive grazing of heath and dry grassland to maintain the rare xerophil and thermophil flora and fauna. The fallowing of wet meadows, generally accepted as suitable, without activities by man might also become a problem with regard to esthetic aspects if, for instance, plant communities rich in *Filipendula ulmaria* and poor in other species developed. The natural development of fallow along the banks of rivers and lakes and in the periphery of forests is very desirable. But here too it is not possible without guiding and forming manipulations if one has not only ecological but also touristic aims in mind.

Total afforesting of all areas abandoned by farmers cannot be accepted. A forest percentage of 60%, and in some mountain regions up to 70%, is considered as the upper limit for forest in Central Europe. Since the forest percentage in the countries mentioned is still essentially under this limit, that is, 30% in the Federal Republic of Germany, the increase of forest is still unobjectionable although the large regional differences and demands have to be considered. The afforesting costs however are considerable. The closer you get to the upper forest boundary, the higher the costs are, until afforesting becomes completely impossible.

Extensive management of fallow land can be arranged by agricultural utilization but also by mowing, mulching (leaving the mowed material on the field) or herbicide application. For an extensive utilization the conditions and the potential yields of these areas are very important. Full-time as well as part-time farming is suitable. In order to do full-time farming successfully by extensive means, large enough farm units either have to be present or be created. This can be achieved by purchase, rent or cooperative farming. Legislative steps

towards an improvement of existing laws for rent and consolidation of scattered holdings are of special importance. If possible, consolidated areas of more than 100 ha should be formed. Quadflieg (1971), for instance, recommends 150–200 ha for profitable sheep farming. Zapf (1972) considers areas of more than 100 ha grassland as necessary and Andreas (1973) uses 100 ha and 3000 starch equivalents (SE) per ha for his model calculations. Steinhauser (1974a) also calculates with 100 ha for a highly mechanized farm specializing in combine harvesting. Part-time farming on arable land is especially suitable for smaller scattered plots. This type of farming requires an efficient and well-functioning machinery cooperative.

Utilization of Arable Fallow Land

Arable farming is especially possible in the hills, in the Jura, in the French "massive centrale" and in other mountain regions with suitable slopes and high plains. Provided one laborer (2200 man-hours/year) can farm 100 ha by combine harvesting (Steinhauser, 1974a), a net return of 16000, DM/laborer/year can be achieved taking into account the present price-cost relations and a yield potential of 30 dt cereals/ha (the commercial salary was DM 16000 in 1973). Since 30 dt/ha can be obtained in hill areas suitable for cropping by means of good mechanical technology, extensive crop farming should be possible without any governmental support. For part-time farming on scattered plots 35 dt/ha are necessary for achieving a parity income of about 7 DM per hour.

Extensive Grassland Management

Extensive management of hill grassland is more difficult. For this type of fallow land especially the labor- and capital-saving methods of extensive cattle- and sheep-farming are suitable. Under special conditions, for instance if agricultural utilization is not possible because of the location of the plots and lack of farms, certain cultivation methods, like mowing, mulching and application of herbicides are of interest.

The organization of grassland management in hill lands is to a considerable extent determined by the quality of the location. According to Steinhauser (1974a), three location variants can be differentiated:

1. *Sheep farming on large consolidated grassland areas with low fodder productivity.* The net yield of such areas is assumed to be roughly 500 SE/ha. For this type methods of shepherding are particularly suited. Although migratory herding, as in southern Germany, still plays a certain role, local shepherding will reach a greater importance in the future. In this case a shepherd, living in one place, moves around in the neighboring regions with his own flock. Since for lamb fattening the fodder quality of these pastures is not sufficient, a more specialized sheep farming offers the best chances, that is the lambs not used for flock replacement are sold for 50 DM/lamb at an age of 1–2 days to specialized fattening farms. Under these conditions 500 ewes per farm (800 reared lambs/year) per 125 ha can be managed by 1.5 laborers. If this farm is provided with buildings and machines, it is true that a profit cannot be made, but the farmer can make it with a support of 150 DM/ha. In case of construction of simple new buildings 225 DM/ha are necessary. Based on 150 ha, 600 ewes, 900 lambs and 1.5 laborers, the support amounts to 65 and 140 DM/ha, respectively. Under these assumptions sheep farming is by all means competitive against mowing and mulching which costs between 50 and 300 DM/ha. This is especially true for difficult locations, like steep slopes and stony or rocky soils. Eckl (1976) calculated the supports for hill land management depending on the number of ewes per farm and on the equipment with buildings and machines compared to landscape management by mulching (Fig. 2) and differentiated three types.

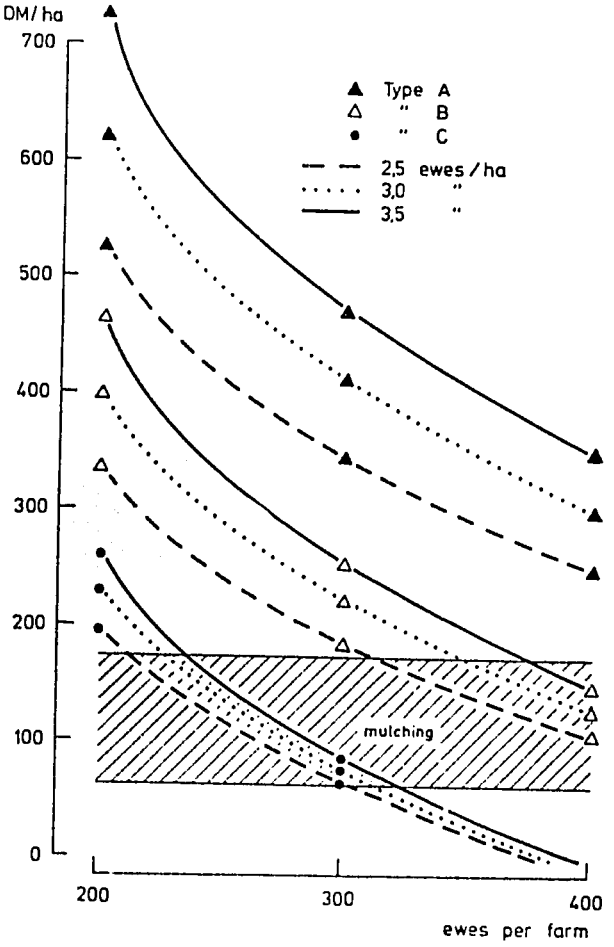


Figure 2. Supports for hill land management with local shepherding compared to mulching by leaving the mowed material in the field (Eckl, 1976).

A: New machines and buildings have to be bought. Plots for winter fodder have to be rented.

B: Buildings and machines are available, but entail permanent depreciation. Plots for winter fodder are available.

C: Buildings are available, cannot be used otherwise and do not cause depreciation. Capacities for machines and areas for winter fodder are available.

Fig. 2 shows that farms of type B with 400 ewes and different stocking capacity/ha can be competitive to mulching. For type C the situation is even better. However, these farms are so-called dying farms, which probably will not be operated in the future. Type A with 400 ewes per farm is not competitive at all. At least 500-600 ewes are required to reach the range of mulching costs. Eckl (1976) assumes that mainly type B will be present in 1980. For this calculation no interest for buildings, machines and mulching equipment is taken into account. Under these conditions sheep farming with 400 ewes per farm is competitive with mulching (Fig. 3).

Depending on the natural conditions, the size of the managed areas and the assumed production technology, the calculated costs for fallow management vary considerably. According to different authors they are:

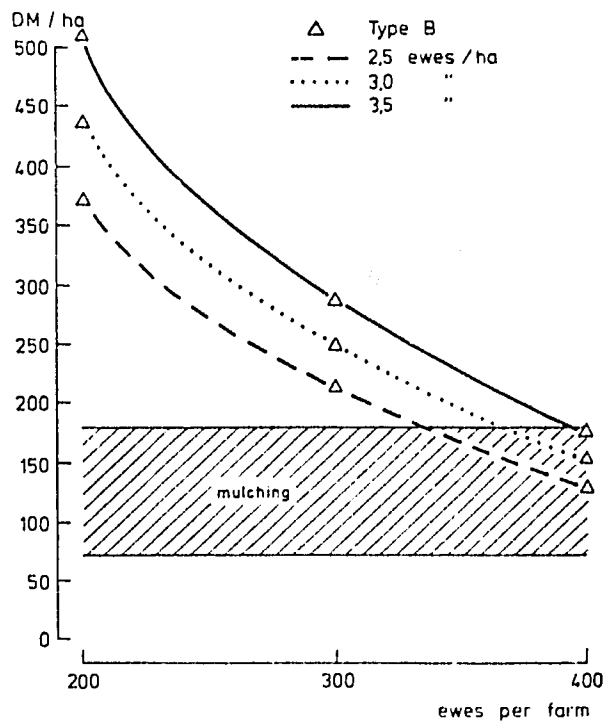


Figure 3. Predicted supports for hill land management with local shepherding compared to mulching in 1980 (Eckl, 1976).

	DM/ha
Sheep farming	50–225
Mowing and harvesting	150–300
Mulching	50–100
Herbicide application	200–250

2. *Management of larger consolidated grassland areas with better fodder productivity* (net yield about 1 800 SE/ha). With increasing location quality, local shepherding and mechanical cultivation compete with extensive methods of cattle farming like cattle boarding, rearing or fattening of heifers and suckler cow herds. Thorough calculations show that on locations like this cattle farming is superior to sheep farming, taking into account the same production technology. Rearing of heifers and cattle boarding can even lead to economic surpluses if buildings are available. If, however, for the management of grassland areas with cattle new buildings have to be constructed, considerable subsidies would be necessary to achieve a net return of 16 000 DM/laborer year. Further details are in Table 4, based on calculations of Steinhauser (1972).

3. *Management of smaller grassland plots with good fodder productivity as part-time farming.* In several hill land locations smaller plots are utilized by paddocking of sheep. However, if one wants to achieve a net return of 7 DM per man-hour from sheep farming as part-time farming, under practical conditions management supports of at least DM 300/ha (Steinhauser, 1974a) resp. 295 DM/ha (Eckl, 1976) are necessary. Paddocking of sheep, however, is only suitable for cultivation of landscape with special limitations because the required fences limit the tourist's way. In addition, paddocking requires an intensification, because otherwise the costs for the fences become too high. Since by this method only small areas with relatively high supports per ha can be managed, paddocking of sheep will not be considered further.

Comparison of the Different Management Systems

Considering the figures and calculations mentioned above, the different methods can be evaluated as follows: In poor areas sheep are the most suitable animals because they are able to utilize low quality forage, are resistant to diseases, and can tolerate adverse climatic conditions. In addition, they are able to move in large difficult areas and to select the most suitable fodder. However, in case of a stocking rate that is too low, sheep grazing has to be combined with occasional aftermowing. If buildings are available, sheep farming is superior to mechanical cultivation. If new buildings are necessary, sheep farming can only compete with mechanical cultivation by applying very good production technology. With increasing quality of location the extensive methods of cattle farming become more

TABLE 4. Subsidy required and surplus, respectively, of management per ha fallow of extensive cattle farming (yield: 1 800 net-SE/ha) (Steinhauser, 1972)

Kind of Farming	Produced Units/year	Managed Fallow Land ha	Subsidy(−) or Surplus (+) DM/ha Fallow Land	
			Old Bldgs.	New Bldgs.
Rearing of heifers (1.5 laborers/farm)	60	70	0 to −30	−275 to −325
Fattening of heifers (1.5 laborers/farm)	95	95	−100 to −150	−300 to −350
Suckling cow herds with selling of store cattle (1.5 laborers/farm)	95[a]	115	−150 to −200	−400 to −450
Cattle boarding[d] (part-time farming)[b]	200[c]	60	+50 to +100	−25 to −75

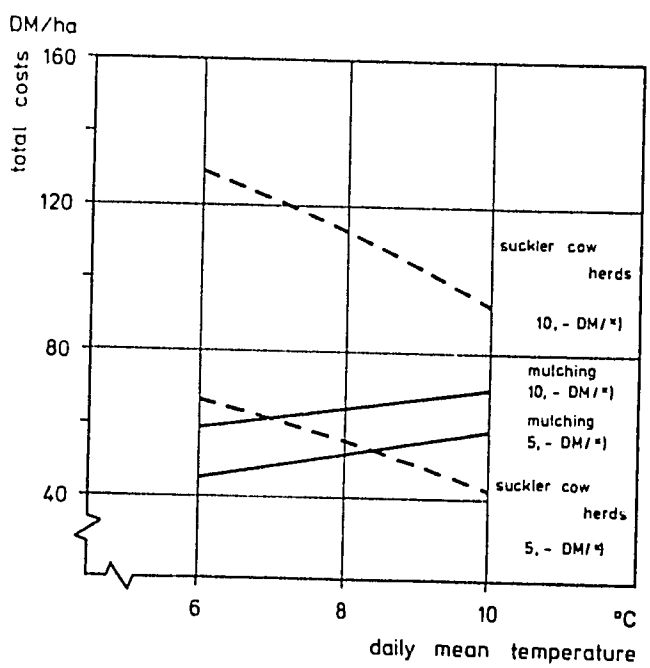
[a] Number of cows.
[b] During grazing season (5 months) one laborer is available for the animals (income 8 000,— DM).
[c] Number of animals.
[d] In German "Pensionsvieh."

and more competitive. With available buildings a net return surplus of 50–100 DM/ha can be achieved by cattle boarding as part-time farming. Rearing of heifers requires only low management subsidies and is then also superior to sheep farming. Suckling cow herds are evaluated differently. Whereas Steinhauser (1972) found them in last place among the different types of cattle farming, Andreae (1973) considered them to be in first place with regard to output per unit of area and to productivity of labor. This might be due to different basic data; however, it also shows that only a few well-founded results exist in this field. In any case the amount of support required increases severely if new farms have to be built. Of course several natural and economic conditions, such as climate and salary costs, have to be considered. The results of Gekle (1975) demonstrate that by variation of these two influencing factors the relative superiority of suckling cow herds against mulching can be reversed. Figs. 4 and 5 show that under suitable climatic conditions cattle farming is superior, whereas under unsuitable climatic conditions mechanical cultivation is superior. Increasing labor costs favor the mechanical methods because the necessary labor input is lower than that necessary in cattle farming.

So far the possible and existing developments of hill land management have been mentioned. Other possibilities, such as hobby-agriculture, horse farming, deer parks, and fishing lakes have intentionally not been dealt with.

Prospects of Hill Land Management

Up until now only a few farmers work as full-time farmers on fallow hill land. The still existing farms are also operated part time to a large extent, which is very difficult to quantify. In order to create farm units large enough for full-time farming, partly insurmountable difficulties exist: (1) scattering of holdings prevents the formation of larger farm units; (2) the experience of two world wars prevents selling and long-term renting of agricultural and fallow areas at economic conditions; and (3) legislative and planning guidelines do not exist to determine the future utilization of all areas in the hill lands. By this fact



x) man-hour

Figure 4. Influence of climate on the costs of different kinds of hill land management (Gekle, 1975).

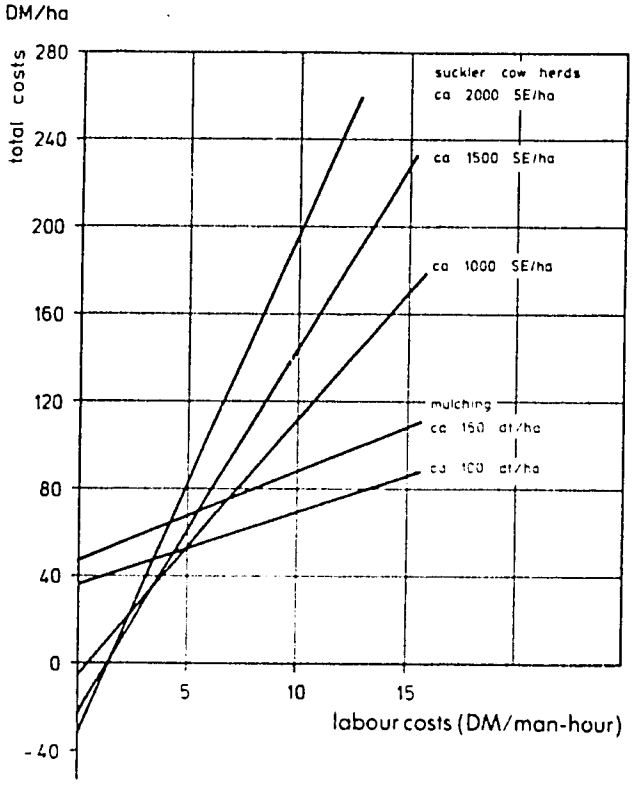


Figure 5. Influence of labor costs on the different kinds of hill land management (Gekle, 1975).

the reallocation of land on a voluntary basis is limited.

In this stage of uncertainty all governments intend to preserve the existing full- and part-time managed farms by subsidies as long as possible, especially in places where no jobs outside agriculture can be created. This is most easily possible in traditional tourist regions, where the combination of cattle farming with tourism has proved to be viable. The recession of the past two years also contributed to the decline of farm abandonment.

As a result only the poorest areas on steep slopes and high altitudes have been given up in the German, Austrian and Swiss hill lands where efficient valley farms with intensive cattle holding are nearby. In this case enough cattle are available for utilization of the alpine pastures from June to September. Only where the farms in the valley are too small has farming been given up completely and along with it, alpine cattle keeping, unless transport of cattle from more distant places can be organized.

The most difficult situation can be found in the hill regions, where tourism has not yet been established or exists only to a small extent. This is also true for the hilly regions of Austria (Plank, 1975). In these areas the inhabitants depend on jobs outside agriculture. Some have jobs far from their homes. Whether they return home daily or on weekends is less important for the land management. This is mainly done by the women or the children and therefore farming is frequently given up totally. In these areas planning of the future land management by extensive cattle farming, afforesting or guided distribution of fallow land as so called ecological cells is of special importance.

Conclusions

A planned management of hill land is definitely necessary for a balance of ecology, water management, structure of population and tourism. It requires legislative and national planning steps to guarantee an optimal distribution of agricultural areas, forests and fallow land with special consideration of all relevant demands.

As long as uncertainties in this field exist, there is justification to maintain the still existing full-time and part-time managed farms by subsidies and to promote the different kinds of extensive cattle farming. This is the best way to create land reserves for periods of crises and to avoid wrong decisions by afforesting at the wrong place. Fallow land, excluded from afforestation, is also to be tolerated because it can be desired on the one side and on the other side can be utilized in another way at any time if necessary. In any case it is clear that any kind of hill land management has to be supported financially. On the amounts of subsidies which are required for the different kinds of management, definite proposals based on several investigations have been made in Central Europe. Of course the costs per ha are not constant but vary with every change of costs for machines, means of production and salary. Therefore the calculations have to be steadily updated, in order to take into account the common interest, and the interest of the manager as well, to utilize and to cultivate the hill land areas.

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DISCUSSION

G. Jung (Pennsylvania, USA). Please comment on how you go about getting the support of legislators and whether you have found it difficult or easy to get the legislation you feel is necessary for wise land use management.

Voigtlander. It is not easy to obtain subsidies from the government, but the situation could be improved if the public is more fully informed.

In any case thorough regional planning must be developed. For this purpose, new laws are necessary. This would enable the farmers to decide whether it is preferable to cooperate with another farmer, to lease or to sell their land. Until now little work has been done in the Federal Republic of Germany except in the province of Baden-Württemberg. Only on the basis of obligatory structure and landscape planning a greater mobility of land will be secured. Then we shall have larger holdings which are necessary for the utilization of fallow land. At present, the owners of the numerous small farms neither are inclined to cultivate nor to sell or to lease their land because they feel that they might need it in the future.

3.
Hill Land Use in the United States

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West Virginia is an appropriate place to discuss hill land. People here have adapted to a rugged landscape. They have faced the challenges that living in this kind of country can present. They also have enjoyed the advantages of hill country living, where the quality of life in some respects is more satisfying than in other parts of the United States.

In one sense, hill land resembles most other kinds of land. It is a basic natural resource. It is available in finite quantities. And demand for it is growing.

In another sense, hill land is unique. It is more adaptable for some uses than for others. Yet it requires some very special kinds of care. How it should be tended depends largely upon how it is used—for agriculture, mining, wildlife, recreation, or forestry, or a combination of these.

An American author, Nathaniel Hawthorne, wrote that "Mountains are earth's undecaying monuments." When that was written—in the middle 1800s—no one would have quarreled with such an observation. But in the twentieth century it has become understood that hills and mountains are much more prone to decay than gentle valleys. Hill land must be protected against erosion after cultivation . . . reclaimed after mining . . . and replanted after timber harvest.

Let us look at some of the major hill land uses in the United States, and at how hill land—a national land resource—can be protected.

AGRICULTURE REPRESENTS THE MOST SIGNIFICANT USE

At first glance, this may seem incongruous, since many characteristics limit the potential of hill land for use as cropland. Its slopes may be too steep. Its soil cover may be too rocky or shallow. It may tend to erode easily under cultivation. But crops are grown on this land—and grown very extensively.

Why plant on such land? Generally, because it is profitable to do so. Potato farmers in Maine achieve very good results on sloping lands. Wheat yields in the hilly Palouse country of Washington, Oregon, and Idaho are among the highest in the world. When it becomes profitable to farm a given tract of hill land, the chances are that it will be farmed. When it becomes vital to increase production of food and fiber to meet worldwide demands, the chances are that more hill land will be farmed. That is the traditional demand-supply formula, and it is still operating.

Although population growth in most of the developed countries has dropped close to the replacement level, populations in less-developed countries are growing at rates better than 2.5%. Total world population has already passed 4 billion and may climb to 7 billion by the end of this century. Not all of these new arrivals or their nations will be able to provide all needed food, clothing, and shelter for themselves. So the United States, which already sends harvests from 3 out of every 10 ha to foreign markets, may be called upon to provide even more commercial and food-aid exports.

At present, these exports consist largely of wheat, other cereal grains and soybeans. But shipments of red meat products are also rising as people become more affluent and change their nutritional levels. Even now, the one-third of the world's population residing in developed nations uses almost as much cereal for livestock feed as the other two-thirds of the world's inhabitants consume directly as food.

This potential demand for red meat could push more hill land into agriculture, since such land can be adapted far more easily for pasture or grazing than for cropland.

Where irrigation is necessary, it can pose a problem. Water naturally runs more readily off sloping land. At certain locations in southern California, sprinkler irrigation or drip irrigation systems have been incorporated into techniques for growing avocados and citrus products on land that slopes up to 70 to 80%. This technique moistens only the area immediately around the plant. It not only conserves water, but also reduces the need for leaching the whole field in order to lower salinity.

Other methods may be adaptable for specific types of agricultural problems, as will be outlined later in other papers at this symposium.

But whether the land is used to raise crops, forage, or livestock, it needs careful conservation attention. Any American who wishes to put his hill land into farming can get help from the U.S. Department of Agriculture's Soil Conservation Service in protecting his soil and water resources. Among suggested conservation techniques are several forms of conservation tillage, including no till. Such approaches reduce the number of times that farm machinery must be driven across the land and keep a plant cover on the ground for longer periods. These methods also permit more efficient cropping on steeper lands. Some good studies using these techniques have been conducted in West Virginia, for example.

Mining

Mining is also a significant activity in hill country. It gives every indication of growing in importance in the immediate future. Among the minerals and metals extracted from America's hill lands are coal, petroleum, natural gas, and uranium. These energy resources are in increasing demand as domestic energy usage continues its upward spiral.

Thus, the United States as well as other countries can expect a concerted effort to step up coal extraction, even as exploration is intensified to find new sources of petroleum, natural gas, and uranium. This translates into further large-scale disturbances of hill land, much of which is currently used as cropland or grassland. Projected energy demand may result in strip mining on more than 2 million ha in the United States by 1980. The Soil Conservation Service is deeply concerned about the possible environmental and agricultural consequences of this development. Our interest lies in assuring that reclamation is included in development plans—that strip-mined land will be returned to a condition suitable for more permanent uses.

The federal government is not alone in this concern. Local citizens, whose lives have been immediately affected by mining operations, share it. In a normal year, West Virginia leads the country in coal production. It mines about 20% of the U.S. total. It also produces and markets more natural gas than any other state east of the Mississippi.

Other areas of the county—from neighboring Kentucky to the Northern Great Plains—also are experiencing a push for higher coal and mineral production. Steps already are being taken to assure that strip-mined land will be reclaimed. In Pike County, Kentucky, for example, conservationists are encouraging landowners to make reclamation a part of their leasing contracts with coal companies. In this way, landowners can maintain—or enhance—the long-term value of their land. Coal companies can begin planning for reclamation from the time the contract is signed. They can begin breaking ground and stockpiling topsoil with ultimate reclamation in mind.

Wildlife

A different situation exists with wildlife and recreation areas in hill country. Many species of wildlife have been able to survive only by making their homes in the rough and remote hill lands. Since many of these birds and animals represent a special kind of treasure, they deserve a special kind of protection.

Man himself often finds a refuge of sorts in the hill country. In the past few decades, more and more people have been constructing vacation homes on American hillsides. Even rising gasoline costs—that make travel more expensive—have not stifled this urge to escape the confines of urban living.

West Virginians are well acquainted with these "leisure time" visitors. More than 10 million vacationers come to West Virginia every year, adding some $600 million to the state's economy. More than 400 000 ha of West Virginia land have been set aside for recreation—mainly in state parks and forests. Recreation is a growing industry in the hill country, and this growth is becoming stronger because of population growth, shorter work weeks, and more leisure time. Thus, hill land is looking more and more attractive to more and more people for use as park and recreation space. Hunters also will want more of these lands for preserves, refuges, and wilderness areas.

Forestry

Another important activity on hill land—forestry—is closely related to wildlife and recreational needs. According to a 1969 report by USDA's Economic Research Service, 58% of the 910.6 ha of land in the United States is privately held. One-third of this land is forest land—most of it in hill country. Almost 80% of the total land area of West Virginia is forested.

Nearly all of America's forests are now under the influence and management of man. In economic terms, this would appear to assure a continuing flow of saw logs, veneer, pulpwood, fuelwood, and other timber products. Yet forest management needs to focus not only on wood fiber production but also on other resource values—like water, wildlife, recreation, and environmental and esthetic qualities. So the ultimate use of any parcel of hill land will probably be determined within a much larger package of total land resource use.

Multiple uses, woven together into a logical overall pattern, represent an optimum avenue for achieving economic, environmental, and other socially desirable goals. In certain instances, for example, some agricultural uses of land may be compatible with programs to provide open space. Many people in expanding cities want to see such open space preserved. Some strip mines may be used for land fills or recreational development; or even returned to crop production.

Putting together such a land-use package first requires answers to two basic questions: What is the most effective use for a given tract of hill land? What steps should be taken to maintain the land in a condition to fulfill that use?

The answers will likely vary from situation to situation, from location to location, and from landowner to landowner.

In a free enterprise society such as the United States', economics often determines land use. What is most profitable to do is often what is done. But not always, for the human element—the public—may be unpredictable. Many people who have established themselves in hill country become strongly attached to their surroundings. They do not take kindly to change, even when that change might mean a higher standard of living.

The extent of resource management needs can also influence land use. Water quality, for instance, is the focus of efforts under Section 208 of Public Law 92-500. The intent of this section is to reduce water pollutants from all sources, including agriculture. Its impact will be widespread. The USDA is assisting the Environmental Protection Agency in preparing national guidelines and policies.

Ideally, technologists should be able to come up with a computer that will weigh all the facts about a given parcel of land and print out a formula for use and treatment of that parcel. But land use is not yet an exact science. While a lot of data already are available—and more data are forthcoming daily—workable land use concepts are still being formed.

So far, planning—by individuals, corporations, or government—planning that considers all values—is the only workable key that can unlock the fullest potential of any given tract of hill land. As conservationists envision it, this kind of planning should move ahead in three general stages: Identifying the most effect use for each tract; developing and using the conservation techniques that will best maintain the land in its desired use; and blending the use of all hill lands with that of other available lands to produce the most efficient national mix.

DISCUSSION

Bob Van Keuren (Ohio, USA). What is being done, or what can we do about protecting some of these ecologically fragile areas such as deserts, mountain meadows, steep slopes with very thin vegetation, from recreational uses such as dune buggies, trail bikes, motorcycles and four-wheeled vehicle racing and so on?

Barry. From a technical point of view, there are many answers that we as scientists and technicians could give that would help preserve and maintain fragile areas. But we are talking about the value system of the people who own those lands vs. the value system of the people who do not own them and have different needs. I do not see it as primarily a technical problem; I see it as one of institutional arrangements for debate about these lands, about

their value and about the need to protect them, that result in some kind of a public policy decision. I would see that in our system in my own organization. We have no control of any lands. The Department of Agriculture has control only of some lands in the National Forest System. Of course the public issue is being raised about some of these very lands. I'm aware, for example, that in parts of the Southwest where feral animals exist, wild horses most particularly, debate going on right now relates both to the National Forest lands and the Bureau of Land Management lands.

I don't know of any real way to resolve that issue except as the public may understand what the problems really are and help to develop public policy.

Maurice Heath (Indiana, USA). We read in the popular press that the USDA has announced that someone has found another 110 million acres in this country that could rightfully go to grain crop production. This seems to me to be somewhat contrary to the teaching we have been getting from the public employees the last thirty or forty years. There does not seem to be enough concern about our forest, pasture, or hay acres. I wonder if you would comment briefly on this—where this land is coming from? Is it going to create further problems? In the Ohio River Valley I'm seeing land that was abandoned a few years ago that has since been rehabilitated with very intensive grassland livestock production on it. With the younger generation coming along, this land has changed hands and is now back in row crop production. I wonder if this land borders on this type of a movement?

Barry. As I understand the issue you have raised, one is the figure now coming out of the Department of Agriculture about there being something like 110 million acres of potential crop lands in the United States vs. the traditional figure of about twice that. I think the concern now is why is the figure only 110 million?

We were involved with trying to assess how many acres of land are available potentially for cropland production in the United States. We found that some parcels are too small to be developed, at least under the current views, because farms are getting larger. Some tracts are too isolated to be developed readily or economically, at least in the time we're thinking about. The survey did indicate that there are roughly about 110 million acres available for cropland production; the inference from this is if we have something like 5 million acres of cropland going into other uses each year, then in 20 to 25 years the amount of potential cropland will be pretty limited in the U.S. There is much more land that could be used for cropland that is now in forest. These acreages are just not conveniently located in the right kind of settings to represent a true potential for development at this stage. There are concerns, then, as to how land will be used.

You may know that the Department of Agriculture has issued a statement about the preservation of prime agricultural land. The Federal committee (Council on Environmental Quality [CEQ]), that deals with environmental impact statements has said that as new developments occur, environmental impact statements are to discuss the impact of moving prime agricultural lands into other land uses. In the Department, and especially in my agency, of all of the issues that have been raised in recent years this one has triggered the feelings of many, many people about the preservation of prime agricultural lands of the United States. Interestingly enough, most of these letters come from non-farmers who are concerned about the losses of these lands. I hear farmers and many other people talk about the fact that farmers represent about 2% of the population and they really don't have much of an impact on the decision-making process as it affects agricultural lands and, more particularly, the hill lands that we're considering here. But the fact is, there is a lot of public concern about the future of these lands.

4.
Hill Country Farming in New Zealand: An Overview

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The steep and mountainous nature of the topography dominates the New Zealand landscape, some 50% of the terrain being classed as steepland (slope > 30°) and 20% as hilly (slope 18°–30°). Of the remaining 30% of land with slope less than 18°, only 3.2 million ha or 12% of the total land surface is classed as plowable. The landscape is largely a result of rapid uplifts in recent geological time

coupled with strong downcutting by streams, and particularly in the south, extensive glaciation. The South Island is dominated by the Southern Alps, a barrier of hard metamorphic and sedimentary rock mountains reaching about 4000 m and flanked on either side by lower ranges of hills of similar material. Low land is limited to intermontaine basins (moraines), alluvial valley plains and border plains, dominated by the Canterbury plains built up on the eastern side of the Alps. In the North Island a hard sedimentary rock mountain chain, of lower altitude than in the South Island, is again the dominating feature, flanked on either side by broad bands of hill country formed from dissected uplifts of more recent sedimentary rock. The center of the Island is dominated by an elevated region of active volcanoes surrounded by a wide plateau formed from the ash of prehistoric eruptions. The low country is limited to alluvial valley plains and sandy coastal strips.

About 13 million ha, or 50% of the country's land surface can be classified pastoral. The remainder comprises approximately 0.5 million ha of arable lands, 6.3 million ha of forested lands, 6.6 million ha of other nonforested land (scrub, second growth, wastelands, barren lands, cities, roadways, etc.) and 0.4 million ha in lakes, rivers, etc. Thus more than 95% of the country's farmed lands is devoted to pastoral farming, nearly two-thirds of which is in sown pastures, the remainder being mainly tussock grasslands (*Encyclopaedia of New Zealand*, 1966).

The 13 million ha of pastoral land can be classed into three main categories (Fig. 1).

Flat and Rolling Country (Intensive).
Hill Country (both wet and dry) (Semi-extensive).
High Country (Extensive).

These categories are based on characteristics such as topography, elevation, climate and especially farming pattern, which in turn determine in the broadest sense pasture composition, productivity and stock-carrying capacities.

FLAT AND ROLLING COUNTRY

A recent analysis (Brougham, 1973) indicates that flat and rolling country comprises a land area of about 4 million ha supporting an animal population of about 60 million ewe equivalents. It has a carrying capacity of something close to 15 ewe equivalents per ha and the average amount of dry matter consumed each year from each ha is about 8000 kg. These animals are paddock grazed throughout the year.

Before European settlement (around 1840) the vegetation of this type of country in the North Island comprised Fernlands, Scrublands, Swamplands and to a lesser extent mixed broad-leaf/podocarp forest (*Podocarpus dacrydium* and *P. phyllocladus*) and Kauri (*Agathis australis*) in the north. In the South

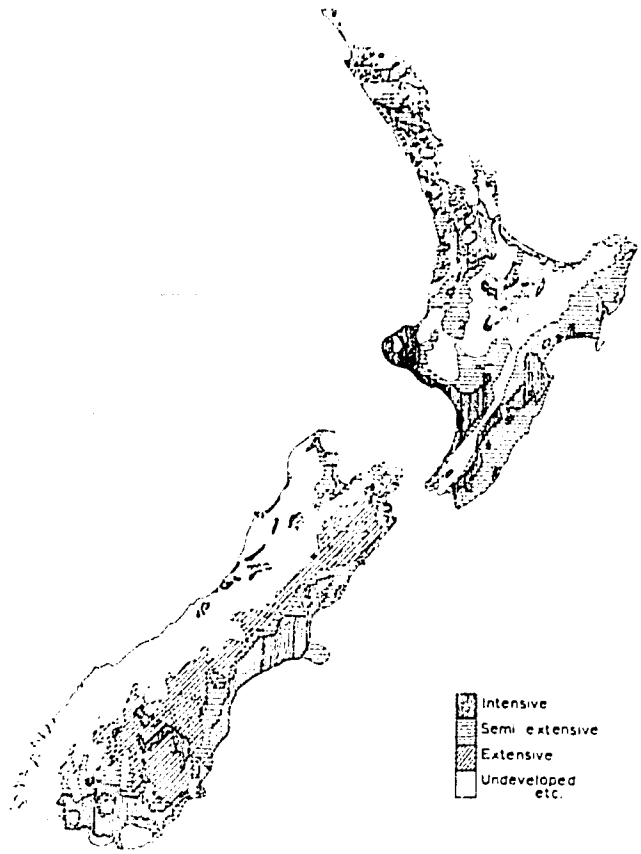

Figure 1. Land utilization of North and South Islands of New Zealand.

Island pre-European vegetation comprised mainly Lowland Tussock Grasslands (*Festuca* and *Poa* sp.) and some mixed broad-leaf/podocarp forests and Beech (*Nothofagus* sp.) forest (Cockayne, 1928).

Considerable areas were therefore badly drained. Following cultivation and sowing most of it required topdressing with superphosphate for successful pasture development. Present-day pastures comprise temperate species of grasses and legumes, especially *Lolium* and *Trifolium* species which grow throughout the year, although showing marked seasonal fluctuations in productivity (Sears, 1953). For substantial high levels of productivity, all soils require phosphate and the more strongly leached soils require lime, potash and some trace elements (New Zealand Soil Bureau, 1968).

HIGH COUNTRY

By contrast the High Country of New Zealand comprises about 5 million ha and supports about 3-1/2 million ewe equivalents. Thus more than one-third of the pastoral lands of New Zealand supports approximately 3-1/2% of its livestock at a carrying capacity of around 0.75 ewe equivalents per ha. The average amount of dry matter consumed

each year from each of these 5 million ha is only about 350 kg. Average farm size is about 12 000 ha.

The original vegetation of these blocks of country, most of which (more than 90%) occur in the South Island at higher elevations was tussock grasslands, sub-alpine grasslands and scrublands. Much of it remains in the original vegetation of *Poa* sp., *Festuca* sp., *Danthonia* sp., *Agrostis* sp., etc. (Cockayne, 1928).

Geologically these blocks of country derive mostly from old sedimentary and metamorphic rocks and small amounts of glacial moraine. Again superphosphate and oversowing of temperate legumes and grasses is a necessary requirement for improved productivity (O'Connor, 1966). This 5 million ha of country, its soil characteristics, vegetation, land use patterns, potentials and problems are discussed in detail by O'Connor (1976) and no further comments are presented here.

HILL COUNTRY

The remaining 4.5 million ha of pastoral lands in New Zealand can be classified as Hill Country. These blocks of country, their development and a discussion of their potential for farming, together with factors limiting or fostering the attainment of this form the remainder of this overview.

The recent analysis previously referred to (Brougham, 1973) indicated that:

1. There are about 4.5 million ha of hill country (both wet and dry) in New Zealand or about one-third of the pastoral area.
2. This area supports about 31 million ewe equivalents, again close to one-third of New Zealand's livestock population.
3. This is an average carrying capacity of about 7 ewe equivalents per ha.
4. The average amount of dry matter that the animals consume each year from each of these 4.5 million ha is about 3 400 kg.
5. Dry hill country has an average carrying capacity of about 3 ewe equivalents per ha and average farm size is about 1 800 ha, whereas the wetter hill country carries about 9–10 ewe equivalents per ha and average farm size ranges from 320 ha on less sloping hill country to 650 ha on the steeper country.

Moist-wet Hill Country. This comprises about 80% of hill country (i.e. approximately 3.6 million ha). Annual rainfall ranges from 1 000–2 500 mm.

Pre-European vegetation was almost exclusively mixed broad-leaf/Podocarp forest in the North Island, with additional areas of Beech and mixed forest in the northwestern area of the South Island.

Geologically, parent materials are both young and old sedimentary rocks plus a considerable area of young volcanic rocks in the central regions of the North Island. Thus all of the wet hill country of New Zealand requires superphosphate to sustain high pasture production levels, and in many regions, potassium, lime and trace elements such as molybdenum, copper, cobalt and selenium are also essential additives for healthy plant and animal growth.

The country is probably much steeper than is normally depicted as hill country in other countries of the world. It is this steepness that adds different dimensions to farming endeavor on hill land.

Dry Hill Country. This comprises the other 20% of hill country that is farmed in New Zealand. Annual rainfall ranges from about 350–1 000 mm. Pre-European vegetation comprised mainly areas of tussock grasslands and scrublands with only small areas in forest. Geologically, parent materials are derived from both young and old sedimentary rocks. Phosphate is required for pasture growth, though in lesser amounts than in moist-wet hill country.

DEVELOPMENT OF HILL COUNTRY PASTURE

Since about 1890, largely aided by government policy, almost all of the moist-wet hill country presently farmed has been developed from forest, fern or scrub. Initially the understory vegetation was cut and burned. Considerable expertise was developed and where properly applied complete destruction of the previous vegetation was achieved, resulting in very satisfactory seedbeds. Temperate grass and legume mixtures were sown by hand in the warm ashes of the burn. The outlook from the outset was to develop a legume based pastoral agriculture; white clover (*Trifolium repens*) and *Lotus* sp. on the moist-wetter country and subterranean (*T. subterraneum*) and white clover on the drier country.

Initially establishment of sown species was good and adequate nutrients from the ash were present for good pasture growth. However, particularly on the higher rainfall country, this initial fertility was soon exhausted. Legume vigor declined, and because of very poor soil nitrogen levels grass species grew poorly and weeds reestablished. Reversion to bracken and scrub then quickly followed.

The requirement for phosphate to sustain legume growth was soon established (Aston, 1929; Hudson *et al.*, 1933) but it was not until the advent of aerial topdressing in the late 1940's that enough phosphate was applied annually to hill country farms to sustain pasture vigor (Campbell, 1949). Successful development was only achieved where stock were also readily available to contribute to the build-up of soil fertility and to control secondary growth, such as fern, kanuka and manuka, tauhinu, and later gorse and broom. As quoted by Levy (1970), "Finance, labour, topdressing, surface-seeding, the erection and intelligent use of fences, the choice of the appropriate class of stock and its management, together with the will and energy to win of the farmer, and often the farmer's wife, were all fundamental

to successful conversion of forest to grass." These requirements, applicable more than 50 years ago, are little different today and apply equally to the improvement of dry hill country.

Much of the early research into wet hill country pasture development considered the use of various temperate pasture grasses and clovers in relation to sowing rates and time of sowing (Levy, 1922), control of regenerating secondary growth of endemic species such as bracken fern (*Pteridium* sp.), pig fern (*Paesia* sp.), kanuka and manuka (*Leptospermum* sp.) and tauhinu (*Cassinia* sp.) (Levy, 1923; Grant, 1966), and type and rate of fertilizing. Many problems have been encountered in the development of New Zealand's hill country pastures (both wet and dry) to their present stage of productivity. Most have been overcome through a combination of trial and error by farmers, research endeavor and advisory officer participation. Briefly these have included biological factors such as "bush" sickness in stock caused by drastic copper and cobalt deficiency in pasture herbage, particularly on pumice country (Askew, 1939); poor inoculation of legumes because of ineffective strains of rhizobia in soils (Sears *et al.*, 1955); major soil erosion problems because of high rainfall (Levy, 1970) or wind in dry country (McCaskill, 1973); invasion of introduced weeds such as gorse (*Ulex europaeus*) and broom (*Cytisus scoparius*); type and methods of fencing; and combination of sheep and cattle to control ingress of weeds and optimize utilization of feed produced.

Progress to a large degree has been governed by economic factors and their associated social effects. The result has been the adoption of farm management practices which, while not ensuring maximum productivity, have ensured economic survival. Some of these have included reduced fertilizer inputs and weed control, adoption of less labor demanding "easy-care" stock management systems through sheep and cattle breeding plans and amalgamation of farm properties.

Unfortunately the above pressures have tended to cause a cyclic pattern of development during the last 40 years. This has resulted in cycles of weed ingress and lowered production when financial returns have been low through to high points where weed control has been practiced, high levels of fertilizers applied, and production has increased.

Nonetheless, the history of development of hill farming in New Zealand has been a successful one. It has resulted in a relatively high carrying capacity for this type of country, the highest recorded presently is 18 to 20 ewe equivalents per ha or 4 to 5 cattle per ha. These figures compare with recorded pasture production levels of up to 22 000 kg dry matter per ha for stock camps, 11 000 to 13 000 kg dry matter per ha for wet hill faces and 2 000 to 9 000 kg dry matter for dry hill faces (Suckling, 1959).

Pasture composition ranges from browntop dominance (*Agrostis tenuis*) with some sweet vernal (*Anthoxanthum odoratum*), Yorkshire fog (*Holcus lanatus*), dogstail (*Cynosurus cristatus*), suckling (*Trifolium dubium*) and white clover (*T. repens*) and *Lotus* sp. (Table 1), and a variable *Lolium* sp. content depending on level of fertility on wetter hill country, to danthonia (*Notodanthonia* sp.) dominant with ratstail (*Sporobolus africanus*), *Vulpia* sp., crested wheat grass (*Agropyron cristatum*), browntop and suckling, clustered (*T. glomeratum*) and striated clovers (*T. striatum*) on drier hill country. The contrast between shady and sunny aspect is particularly marked in this type of country, with shady aspects more closely resembling moist hill country pasture composition.

Marked improvements in productivity on hill country are possible. Recent research (Suckling, 1975; Grant, personal communication) indicates that carrying capacities can be increased by a factor as great as 3 if limitations of phosphate and other nutrients are removed and a more uniform return of dung and urine of grazing animals is achieved through better husbandry practices, particularly frequency, duration and intensity of grazings. Marked changes in botanical composition can be achieved resulting in greater amounts of ryegrasses (*Lolium* sp.), cocksfoot (*Dactylis glomerata*) and white clover. Pastures of this composition have a longer growth period than the markedly seasonal curve of browntop

TABLE 1. Extremes in pasture composition of moist-wet hill country and comparable flat land (% occurrence per 100 sampling cones—7. cm diameter)

	Browntop	White Clover	Ryegrass	*Poa trivialis*	Yorkshire Fog	Dogstail	*Danthonia*	Chewings Fescue	Sweet Vernal	Moss
Hill country	61	51	43	11	26	33	12	17	16	38
	97	29	2	—	22	20	33	17	66	62
Flat lands	3	90	97	73	—	1	—	—	4	—
	58	95	59	70	27	11	—	—	3	—

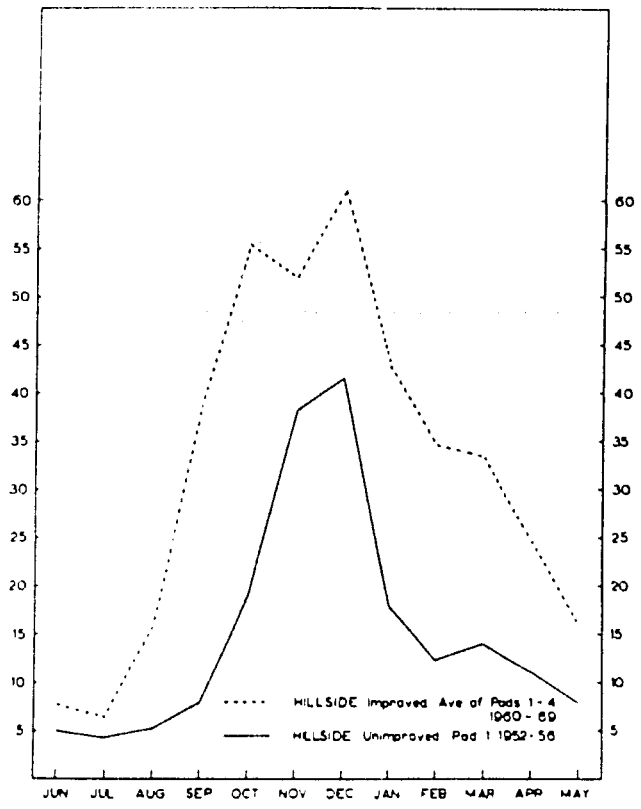

Figure 2. Comparison of annual pasture production from improved and unimproved hillsides in moist-wet North Island hill country (after Suckling, 1975).

dominant pastures (Fig. 2), resulting in markedly superior performance of animals and much higher carrying capacities.

The hypothesis being propounded is that the carrying capacities of hill country farms in New Zealand could be as high as those on flat and easy rolling country. Whether this occurs will be almost totally dependent on whether New Zealand can adopt a long-term internal plan of agricultural development in the present world climate where cost inflation, recessions, trade barriers, political expediencies, and many other restrictive factors are predominant and importantly are beyond the influence of the New Zealand farmer in his export drive. New Zealand is more than 80% dependent on export of agricultural products to earn overseas funds.

The data presented in Table 2 indicate levels of profitability experienced by New Zealand hill country farmers this past decade. Statistical data are presented on a per farm basis for North Island steep hill country, both moist and summer dry, and easier hill country. Of significance to this discussion is the fact that percent returns on capital invested ranged from 4.19% to 10.76% with a 6-year average of around 6.2%. This occurred when investment opportunities in other sectors of the economy were returning up to 12% for government-approved investments and 15–20% for second mortgage or hire purchase capital.

Returns on capital such as those shown in Table 2 are far from adequate to finance farm development plans to overcome known major limiting factors to

TABLE 2. Production data from a survey of North Island, New Zealand hill country farms (per farm average—6 years)

Year	Type hill country	Effective area (ha)	Total stock units (ewe equivalents)	Total fertilizer (mt effective ha)	Gross income ($)	Net income ($)	Total capital[a] ($)	Return on capital[b] (%)
1968–69	HH[c]	753	5 654	.153	26 272	6 908	121 818	4.90
	H[c]	334	3 530	.334	19 355	6 201	96 166	5.30
1969–70	HH	734	5 530	.164	29 206	9 443	138 571	5.92
	H	334	3 491	.222	21 330	7 377	110 325	5.25
1970–71	HH	651	5 186	.140	27 021	7 351	140 966	4.19
	H	335	3 453	.196	20 508	6 470	115 871	4.33
1971–72	HH	647	5 153	.173	31 445	10 133	145 823	5.85
	H	340	3 431	.212	23 584	8 465	121 103	5.59
1972–73	HH	655	5 279	.206	52 733	25 377	217 400	10.60
	H	350	3 601	.272	41 451	22 123	183 417	10.76
1973–74	HH	673	5 306	.203	48 562	16 271	249 965	5.53
	H	347	3 530	.252	38 238	15 977	205 848	6.40
Average (6 yr)	HH	685	5 351	.173	35 873	12 580	169 090	6.17
	H	340	3 506	.248	27 411	11 102	138 788	6.27

(New Zealand Meat and Wool Board's Economic Service, Sheep Farm Survey.)

[a]Excluding house and car.

[b]After adjusting net income for managerial reward, interest and rent.

[c]HH = Hard hill country.
H = Easier hill country.

achieve potentials. On most farms these include:

1. The need to alter botanical composition of pastures from browntop dominance to a dominance of temperate grasses and white clover. This can be accomplished through better fertilizer regimes, more adequate stock control (fencing), and hence better cycling of nutrients in dung and urine, resulting in a better fertility build-up.

2. The need to develop better networks of "on-farm" roads for accessibility and stock movement, and to establish better water distribution systems for stock water. There is also the need to develop better national road networks for the more remote areas.

3. The need to control secondary growth, pasture pests such as *porina* sp. (*Wiseania* sp.) and grass-grub (*Costelytra* sp.) and erosion. For example, present-day costs of scrub clearing on badly reinfested country can be as high as $250 per ha. Seed, fertilizer and fencing are additional costs.

4. The need to improve the quality of feed for livestock throughout the year and to develop sheep and cattle that require less attention and have a higher fecundity. Hight (1976) discussed these aspects in more detail.

These and other limiting factors can be ameliorated. During the past 30 years, research and industry have developed sophisticated aerial topdressing techniques, produced chemicals that adequately control secondary growth, and developed breeds of sheep and cattle that require much less daily care and have a much higher fecundity. Techniques such as seed coating also ensure more successful plant establishment from oversown seed, and methods of electric fencing have been developed for even difficult hill country. These are less than one-tenth the price of conventional post, batten and wire fencing.

In spite of these and other developments that will surely come from research, farmer innovation or advisor assessments, the future use of New Zealand's hill country, and in our view much of the hill country of the world, will be determined mainly by economic and social factors.

Economic factors could cause New Zealand's hill country to intensify in terms of pastoral agriculture and become very productive. It could just as easily cause pastoral agriculture decline and a wilderness of secondary growth and reestablishing native forest develop, or, again, depending on economics, exotic forestry or a mixture of pastoral and forest farming could develop over large areas. If the hill country did revert to secondary growth these regions could still have some sort of economic future as leisure and tourist areas.

These trends could be halted or altered through social pressures. There could be a migration of some of the population back to rural living, either by those that like the simple way of life or by those who are higher income earners and thus have capital to farm smaller uneconomic units regardless of profit, because the hill country is usually a nice place to live. And isn't that the way the early pioneers of most countries that have been developed this past 200 years or so saw it? On the other hand, social pressures could force governments to ensure internal profitability in hill country farming, and thus sustain the impetus for development and maintain the inputs of the last 80 years in land development, roading, reticulation of services and community establishment.

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5.
Land and Life in the Nepal Himalayas

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PHYSICAL AND CLIMATIC FEATURES

The Himalayas have been recognized as the youngest mountains on earth. Nepal occupies the major part of the Himalayan range with the highest peak in the world—Mt. Everest. It lies between longitudes 80° and 88° E and latitudes 27° and 30° N. Nepal is about 800 km long and its width varies from 160 to 240 km, the total area being 142 080 square km. The lowest altitude is about 80 m in some parts of the south. The rise in altitude takes place gradually right from the southern border. However, in our context it is called Tarai—the low land. There is a gradual rise to 1 500 m north of Tarai which is called the Siwalik Range. This is followed by a sudden depression causing in some places a flat land almost at the same altitude as the Tarai which is called the Inner Tarai. Thereafter there is another rise in altitude to 3 500 m with numerous folds of mountains called the Mahabharat Range. It cradles few valleys like Kathmandu (1 350 m) the capital of Nepal, Pokhara (810 m) and many more. These folds of mountains are continuous until they rise to 8 848 m to the peak of the Mt. Everest. This is called the Himalayan Range. It extends right from the east, travels along the northern border, and enters slightly inside the middle part of the country in the western and far western region, providing still a diversified landscape beyond the Himalayan Range identified as the Inner Himalayan Region similar to adjoining terrain of the Tibetan plateau (Hagen, 1970).

The climate varies from cold arid in some parts of the north to hot and humid in the south. As the altitude rises, temperature becomes cooler and pleasant until it becomes very cold. The maximum temperature in West Tarai goes up to 39°C in May, but averages only near 30°C. Because of the altitude there is variation in the climate. The monsoon rainfall is highly seasonal with about 85% of rain falling in June to September. Annual rainfall decreases from around 2 000 mm in the east to less than 1 000 mm in the western part of the country. Winter has scanty rainfall. There are large local variations of climate associated with the altitude and topography. The drainage system provided by the Kosi, Gandaki and Karnali rivers flows from the Himalayas to the south. Some of the rivers—the Mahakali, Karnali, Trisuli, Sunkosi, Tamakosi and Arun—originate in Tibet. River gorges and steep mountains have made this country vulnerable to erosion.

STRATEGY OF DEVELOPMENT

Accepting the challenge of identifying the possible future economic potential, the country has been divided into three agricultural regions based on ecology—Tarai, Hills and Mountain. Primarily, Tarai has been identified for the production of the food grains and industrial crops, Hills for horticultural crops and Mountains for pasture and livestock (Anon., 1973).

OCCUPATIONS

Traditionally, the mountain people keep chauris (a cross breed of Tibetan Yak and Nepalese cattle), mountain goats, sheep and horses as their supplementary source for food and clothing (Shrestha, 1975). They also cultivate some suitable patches of land to raise naked barley, barley, buckwheat, amaranthus, maize, peas, beans, potato, radish and at Jumla, at 2 700 m, even rice. But their major income came from trade with the north and the south before the close of the northern border. Salt, wool, natural dyes, herbs and dry meat from the north were bartered for the food grains, soap, candles, shoes, cloth, sugar and brown sugar from the south.

In the new situation, where trade does not exist, they have adjusted themselves mainly by intensifing their activities in livestock, diversifying their trade to tourism, trekking and mountaineering and trade within the country and overseas. Part of their leisure time is being utilized in cottage industries such as carpet making and weaving. However, food is in deficit and we need to supply it (Table 1). People of this region are either Tibeto or of Tibeto-Nepalese origin. Their religion is mainly Buddhism (Bista, 1972).

The Hill regions, situated north of the Siwalik Range and midland of the Mahabharat range mostly facing south have been climatically favored since even during heavy malarial infestation in the Tarai in the past, these areas were free from it. The climate varies from subtropical in the lower altitude to warm-temperate at higher altitude. This climatic condition has favored migration to this region. The main occupation is agriculture supplemented by animal husbandry, beekeeping, fruit cultivation, and cottage industries. The principal food crops of this area are maize, rice, millet, potato and wheat. The Hill area produces more per unit area of land compared with Tarai because of the hard working

TABLE 1. Food production situation in Nepal, 1974–75

Region	Area under Cultivation (thousand ha)	Physical output Cereal grains (thousand MT)	Edible cereal Grain available (thousand MT)	Population[a] (thousands)	Edible cereal Grain requirements (thousand MT)	Balance +Surplus −Deficit (thousand MT)
Mountain	115	182	138	1 139	180	− 42
Hills	732	1 382	912	6 071	970	− 58
Tarai	1 370	2 337	1 300	4 946	825	+475
Total	2 218[b]	3 901	2 350	11 556	1 975	+375

[a]Population statistics 1972.
[b]Exclusively used for food production.

nature of the people and intensive cropping pattern wherever they irrigate (Anon., 1975). However, the total food produced does not meet their requirement (Table 1). Need of subsidiary income to meet the deficit of the food compelled many people to move to the Tarai region for cultivation and settlement, and also to other parts of the country in search of jobs. New jobs, like sale of milk and milk products, have appeared. Also, the supplying of firewood in the town area has become a regular occupation. The traditional bamboo baskets made for home use have become an important commodity for trade. Top quality fruits, mandarin oranges, pears, guava, bananas, lemon and lime, grown in the Hill area provide subsidiary income to meet the daily needs of salt, oils and kerosene. The cultivation of broadleaf mustard, beans, cucurbits and radish are of traditional nature. Recently many new types of vegetables such as cabbage, cauliflower, carrots and a few others have also been introduced. Fruit trees of citron, lemon, apple, pear, peach and many other food and root crops are found wild in the Hills. Thirteen Nepalese ethnic groups whose dialects, cultures and traditions are diverse live in the Hills.

The Tarai, once covered with salwood forest (*Shorea robusta*), has been turned into cultivated area. People practice monoculture, cultivating rice as a single crop in summer in flat areas and maize in the uplands. Jute, sugarcane and tobacco are being cultivated where climate is favorable and as per the need of the factories. Wheat is grown in winter where irrigation is possible. This area is surplus in food grain (Table 1) which is Nepal's principal export commodity.

Nepal is predominantly an agricultural country contributing about 66% of national income. Agricultural commodities comprise 75% of the total export and constitute 80% of the total foreign exchange earning (Anon., 1973). The total cultivated land is 16%, of which only 10% is under irrigation. Nearly 58% of land is under paddy, 21% under maize, 15% under wheat and barley and 5% under other crops (Table 2). Of the 14 million head of livestock, 43% are cattle, 24% buffaloes, 30% sheep and goats and 3% other animals. About 29 000 ha are under fruits and 60 000 ha under vegetables.

LAND AND MAN

Out of 2 218 000 ha of cultivated land, 62% is in the Tarai and 38% in the Hills and Mountains, whereas the population pressure is just the reverse. The population density per ha is 8.5 persons in the

TABLE 2. Area and production by ecological regions, 1974–75

	Mountain		Hill		Tarai		Total		Percentage	
	Area (thousand ha)	Prod. (thousand MT)	Area (thousand ha)	Prod. (thousand MT)	Area (thousand ha)	Prod. (thousand MT)	Area (thousand ha)	Prod. (thousand MT)	Area (thousand ha)	Prod. (thousand MT)
Rice	17	36	236	577	1 032	1 913	1 285	2 526	58	64.7
Maize	44	85	280	565	144	204	468	854	21	21.9
Wheat	31	36	114	125	168	196	313	357	14	9.2
Barley	9	9	12	11	8	8	29	28	1.4	0.7
Millet	7	8	73	86	17	15	98	109	4.4	2.8
Buckwheat	7	8	17	18	1	1	25	27	1.2	0.7
Total	115	182	732	1 382	1 370	2 337	2 218[a]	3 901	100	100

[a]Exclusively used for food production.

TABLE 3. Land and population relationship, 1974–75

Region	Total Land (thousand ha)	Cultivated Land (thousand ha)	Distribution (%)	Cultivated land (%)	Population (thousands)	Distribution (%)	Density Persons (no.)	(ha)
Mountain	4 678	115		2.46	1 139		8.5	
Hill	6 263	732	38.2[a]	11.69	6 071	62.39[b]	8.28	8.5
Tarai	3 267	1 370	61.8	41.93	4 346	37.6	3.17	
Total	14 208	2 218[b]		15.61	11 556		5.21	

[a]Mountain and hill combined.
[b]Exclusively used for food production.

Hills and 3.17 persons in the Tarai (Table 3). In spite of the intensive cultivation in the Hills the production could not fulfill the needs of the people. Agriculture is merely at subsistence level. Population growth of 2.02% there is outpacing the national average of 1.9%. Every year nearly 200 000 people have to be accommodated in agriculture because of absence of other occupations. This is particularly the case in the Hills.

RESETTLEMENT

Although a resettlement program in Tarai for the Hill people was launched early in 1960 it has been effective in a planned way only since 1963. By now more than 7 300 ha of land has been distributed to 5 500 families (Deoja, 1975) and the Nepal Resettlement Company plans to resettle 19 000 families in 43 000 ha of land within four years (Anon., 1976). Similarly, 850 ha of forest encroached by 1 230 families have been registered in 1975 (Anon., 1976). Altogether 477 000 people migrated from the Hills to the Tarai between 1961 and 1971 (Elder *et al.*, 1974). Similarly, encroachment has been going on in the Hills, the extent of which is not known exactly.

FUEL

The only source of fuel for cooking and heating is firewood which is being collected from the forest free of cost. With the increasing population and the demand for food, housing materials, fodder for livestocks and wood for cooking and heating, trees have been cut so extensively that the Hills look barren. In 1967 the areas under forest and crops were 53 and 39% respectively, whereas the crop area now has gone up to 62% (Anon., 1967). As a result, people have to trek a long distance for firewood. In some parts of the Mountains, especially Mustang and in eastern Tarai, animal dung is being used as fuel in the absence of firewood, making cattle manure unavailable for food production. Recently a biogas program has been launched on a trial basis. This seems to be a practical solution for fuel, especially in the Tarai where temperature is favorable for microbial activity. This will also conserve manure which otherwise would have been burnt and wasted. Petroleum products are too costly to be used in general yet, though substantial amounts are being imported. At present Nepal has vast resources of water power amounting to 83 million kilowatts, a capacity comparable to the United States, Canada and Mexico combined (Eckholm, 1976). At present about 40 000 kilowatts have been harnessed. If the available hydro power is harnessed as required, Nepal need not depend on any other kind of energy. The difficulty lies in the absence of the financial investment and needed technology. Some people are trying to utilize solar energy too, but the initial cost seems to be the limiting factor.

TRANSPORT

The motorable road in the Hill and Mountain Region is almost negligible. Nearly all transportation is by foot by both men and animals. Air transport is quite costly. This situation makes it difficult to supply food materials in the deficit Hill Regions.

EDUCATION

General literacy is only 14% (Anon., 1974). There is one Agriculture and Animal Science Institute under the Tribhuban University which trains only medium level technicians. There are a very few trained people who know the need of the Hill and Mountain Regions but they generally do not like to work in those regions because of the very difficult conditions there. Hence their knowledge and education have been of little help to the people of the area. Most of the Hill people are left beyond the reach of education because of their subsistence living.

HILL FARMING CONSTRAINTS

Hill farming has already lost the balance between production and demand. The shortage of land for cultivation and grazing, the scarcity of firewood, the limitation of compost, the lack of animal power, the tightness of the cropping pattern, the seasonal shortages of labor, the shortage as well as uncertainty of rainfall and non-availability of irrigation, limitation of credit facilities, poor transport systems, insufficient storage and market facilities and absence

of appropriate technology all are constraints for agricultural development in the Hills and Mountains.

Besides the rough terrain condition of the Hills, intensive cultivation and opening of the marginal land for cultivation by clearing the needed forest area have invited man-made erosion intensified by monsoonic rains which brought landslides as everyday features of recent years. The Hill eco-system has been disturbed. The rational balance between land, man and livestock has been lost. According to Dr. Eckholm, there is no better place to begin an examination of deteriorated mountain environment than Nepal (Eckholm, 1976). In fact, this situation has threatened the life of the people in this land.

CONCLUSION

The Hill environment certainly needs to be restored so that Hill people can lead a better life and to protect the vast area below it from flooding and silting. An eco-system has to be established in which man, animal and plant can co-exist without losing the top soil, the formation of which takes years and years. Besides labor, the soil is a major part of the capital of Nepal in the absence of other explored resources such as water, sunshine, minerals, gas and biogas. Considering the serious situation in the Hills of Nepal, a seminar was recently held in Kathmandu July 8 and 9, 1976, on the development and management of energy resources in the Hills. This was organized jointly by the Institute of Applied Science and Technology, Tribhuban University and the Swiss Association for Technical Assistance. The energy resources visualized were forest for fodder and fuel, water for hydro power, biogas for methane gas and manure, solar energy as alternate energy for fuel, and food and fodder for man and livestock—which could be derived from the combinations and interactions of soil, labor, water, plant life and animal life.

The point is that although improvement of Hill agriculture is a technical problem, it is not possible to dissociate it from administrative, organizational, cultural, legal and social problems. When we think of Hill agriculture in the light of land and life this demands an integrated approach from the concerned fields. The program on Man and Biosphere (MAB) has also put more emphasis on the integrated study of the requirement of the Mountain and Hill area (Anon., 1973). The MAB conference held in Nepal from Sept. 26 to Oct. 2, 1975, made a recommendation for the establishment of an Institution for Mountain Environments. Some organizations of the developed nations have carried expeditions to the Himalayan peaks and made some studies merely in the quest for knowledge, and these are mainly academic. Moreover their publications are mostly in languages other than English, making their knowledge not readily available.

In the text of the above situations there is an urgent need for an International Institute of Hill Agriculture in the Himalayan Region which will be able to restore the land and the life of the people.

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DISCUSSION

K. F. O'Connor (New Zealand). You mentioned in the abstract of your paper that the Himalayas are the youngest mountains in the world. In your understanding of trying to plan mountain land use to reduce sediment load and sediment transport, do you believe that your government agencies are taking full account of the youth of the mountains? In this condition a large volume of erosion is inevitable. That a large proportion of it is taking place, especially in the riparian situation, just cannot be avoided by mountain land use. I'm asking you, therefore, to distinguish for us between the importance of accelerated erosion, such as I know that you have, but which I believe is overestimated, in comparison with geologic erosion.

Nepali. The impact of the erosion is very serious. This is what I want to put forward. And regarding the importance of the two forms, I would say it

depends upon the individual persons involved in deciding these factors. Normally in the mountain country I must confess that the people who decide are not those on the hills, but instead the upper class people who do not really know the situation. In the future, of course, we will take account of the situation, and the government is quite aware at the moment of the need to control the situation. In fact, government is working on how to use hill land so that the soil is not eroded and ultimately soil is retained there for future production and a better life for the people.

O'Connor. I hope that you do not believe that all the erosion problems of Nepal can be managed—some of them just have to be lived with.

Nepali. It is like this, we have different erosions; one is man-made, which can be controlled and one is natural; we have to accept this.

R. Nelson (West Virginia, USA). What specific programs or projects do you have which give some indication of success in limiting the deforestation you mentioned?

Nepali. We are planting the hill lands under forests wherever possible, even where the people have left because they could not get a good crop. I have already indicated in my paper that in the long-term perspective, government has decided to have horticultural crops in the hill area and forest crops. These are some of the crops which may stop erosion. In my opinion, we should have a closer contact between the livestock and horticultural activities, like fruit crops. They could be planted in a certain distance, and forest crops could be grown in between, very simply, and the livestock would be brought in for grazing. The farmer could then have both crops of fruit and products of livestock which could be bartered or marketed in the plain area so that economic integration could be established between the plains and the hills.

James Duke (Maryland, USA). In Bolivia I saw some terraces similar to those that you showed and there was a big argument about them. One man said that the terraces prevented erosion and the other one was saying that terraces accelerated erosion. Do you have any comment?

Nepali. Well, terracing is one of the main systems of controlling erosion. Special terraces are made in Nepal where irrigation is available or where they can store the water during the monsoon season. They can get paddy crops up to the altitude of 5 500 feet where we have our terraces and beyond that it is all in the rolling mountain where there are no terraces. Now these areas are being explored for cultivation of maize and other things. This is the area which is prone to high erosion. Terracing is one of the factors which controls erosion.

G. Anderson (West Virginia, USA). You indicated that sometimes it's difficult to get technological improvements brought into the higher hill areas, and recently it's come to my attention, in some reading, that roads have been placed through to accelerate and to improve communication and transportation. Are these roads a positive or negative factor in terms of long-term development? Does the cost exceed the potential contribution?

Nepali. Well, at the moment I will not comment in the negative, but the roads open in the hill areas travel along the river basin and when you go to the high mountain regions the flat lands are on the top of the hill and the roads are below it. Of course it is in walking distance of one or two days or even a few hours. This is the situation, but, frankly speaking, I have already mentioned that people who have been trained in agriculture are likely to concentrate in a place where there is less difficulty, like in the plain areas. We have a lot of trained people there and also in hills like Katmandu, but they don't like to go into the high mountains. Even if you post them there they think of many reasons to come back. This is why there is difficulty in transmitting the technology. Moreover, the technology which we have hasn't been fully tested as to whether or not it is applicable in the high hills.

6.
Hill Land Agriculture in the Humid Tropics*

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The Humid Tropics (HT) are very difficult to define satisfactorily. Efforts to define them according to climatic factors, notably humidity and vegetation, resulted in very different boundaries (Fosberg, Garnier, and Küchler, 1961). In his important paper on productivity of the HT, Chang (1968) chose Köppen's (1900) Af climate as the boundaries of the HT, choosing to leave out Am areas.

For purposes of this paper, the HT are defined as those lands receiving at least 1 000 mm of rainfall and which lie north of the Tropic of Capricorn and south of 25° N latitude. Generally they include those lands classed as tropical rain forest and which lie within two major climatic classifications, namely: Af and Am areas (Köppen, 1900). Here, A = rainy climate with no winter and the coolest month above 18° C (64.4° F); m = monsoon rain with a short dry season which is compensated for by heavy rains during the rest of the year; and f = constantly moist, rainfall of the driest month at least 60 mm (2.4 inches).

LAND AREA

Because HT boundaries are so much in question, it is difficult to estimate how much land area, and, then, the amount of hill lands which fall into this region. Chang (1968), using the Af climate as the boundary for the HT, estimated an area of about 550 million ha (2.1 million square miles), or 4% of the earth's land area. Staszewski (1961), cited by Chang (1968), estimated that Af and Am climates together amount to 8.1% of the total land area of the earth and contain some 7.95% of its population.

Great land areas of continental South America and Africa lie in this region, as do most of Southeast Asia and much of South Asia.

Several large countries have large land areas in the HT. These include Brazil, Colombia, Venezuela, Zaire, Angola, Nigeria, India, Burma, Thailand, Indonesia, Malaysia, the Philippines, Papua New Guinea, and The People's Republic of China (PRC). The PRC has some 1 million square kilometers of land in the HTs, and probably more than 110 million people of the PRC live in that region.

Estimating the amount of hill lands in the HT is difficult. First, it is necessary to define what is meant by hills, and mountains too for that matter. These terms are subjective; for that reason the following landform terminology presented by White and Renner (1948) may be useful.

A. Elevation terms (above sea level).
   1. lowlands 0–600 m
   2. uplands 600–1 800 m
   3. highlands more than 1 800 m.

B. Slope terms
   1. *Hills*—an area with sloping profiles, and only limited relief; gentle to steep slopes, less than 10% level land; regional slopes 4 to 10 degrees; local relief-several tens or a few hundreds of m.
   2. *Mountains*—an area of slope land culminating in peaks or rounded summits. Mountains differ from hills in amount of relief, not in steepness of slope; mountains may be rounded or rugged, with regional slopes 10 to 20% or more, and with local relief from about 1 000 m to several thousands of m.

In this paper, agriculture of both hills and smaller mountain areas will be discussed. The designation of "lowland hills" and "upland hills" may be useful in delimiting the types of agriculture practiced. Highland agriculture (above 1 800 m) will seldom be discussed, for it is rather more related to temperate zone agricultural systems, albeit with tropical or subtropical day lengths.

How much hill land is there in the HT? This is difficult to answer, but perhaps as much as 60 to 75% or so of the total land area may be a reasonable estimate.

CHARACTERISTICS OF HT HILL LANDS

HT areas are characterized by high rainfall and by occasional intensive storms, although most rainfall results from convection or orographic air movements. The high rainfall allows luxurious growth of native trees and vegetation and for planted crops as well.

As elevation increases, air temperatures and humidity decrease. Hills usually also have a lower incidence of insects and diseases.

Hill lands vary widely in origin and morphology, including plateau margins; foothills; sharply dissected areas caused by heavy action of wind or water; volcanic cones; craters, ash deposits, etc.; collapsed limestone areas or uplifted sediments. Each of these

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types presents its own set of problems and potentials for management.

Soil characteristics vary, but are influenced most by parent material and age. Many lowland HT hill lands are Oxisols or Ultisols. Andepts, Entisols, and other Iceptisols are also common, but do not usually present as many management problems as the heavily weathered, infertile Ultisols. Ultisols often require heavy inputs of fertilizers and soil amendments to make them productive, and their inherent low fertility causes great difficulty for small farmers. Oxisols usually have excellent physical properties. Some Ultisols may be less susceptible to erosion than some of the Oxisols (Table 1). Entisols are often too stony for cultivated crops; hence they are often used for tree crop farming. Coupled with judicious use of cover crops and minimum tillage for inter-cropped food crops, Entisols can be successfully cultivated. Some very productive tree crop/food crop systems can be found on Entisols of the volcanic Pacific Islands, the so-called "high" islands of Polynesia and Melanesia.

TABLE 1. Soil erosion K values for selected Hawaii soil families (Dangler *et al.*, 1976)

Soil Family	K(dry)	Erodibility Class	K(wet)	Erodibility Class
Humoxic Tropohumults				
upper	0.	Very low	0.	Very low
lower	.02	Very low	.14	Low
Vertic Ustropepts	.03	Very low	.41	Moderately high
Tropeptic Eutrustox	.09	Very low	.20	Moderate
Typic Torrox	.09	Very low	.23	Moderate
Typic Chromusterts	.26	Moderate	.31	Moderate
Typic Torrox	.41	Moderately high	.31	Moderate
Typic Hydrandepts	.08	Very low	.07	Very low
Hydric Dystrandepts	.12	Low	.22	Moderate
Typic Eutrandepts	.16	Low	.26	Moderate
Entric Eutrandepts	.60	Very high	.51	High

Soil texture plays an important role in cultivation of HT hill lands, especially in regard to potential erosion with repeated exposure to heavy rains. Highly aggregated soils are usually not as susceptible to erosion; however, soils with aggregates which weaken with wetting can erode much more than when dry.

Soils which are likely to suffer from soil creep on hillsides can lead to serious landslides. Landslides may be accelerated if subsoils contain a distinct clay layer providing a slippery substratum which, when moisture conditions are correct, may slide and carry the upper layers downhill.

Gully formation can be severe in some soils particularly with repeated removal of protective cover and under high rainfall. Older soils developed under high rainfall and with very high infiltration and percolation rates will be less susceptible to gully or sheet erosion than younger, less porous soils.

Shallow soils on steep and/or stony slopes can lead to problems, including shallow or poor root development, rapid runoff, poor nutrient supply and low water-holding capacity.

FACTORS AFFECTING HILL LAND USE

Many factors influence the use of hill lands in the HT. Some of the more important factors will be discussed here, but the subject is much too complex to be given more than a cursory treatment.

The Hunger for Land

Burgeoning populations in many countries have caused tremendous pressure on hills and other marginal lands (Pereira, 1973; Eckholm, 1976b). Large numbers of landless laborers in many countries are moving into the hills in large numbers as squatters and shifting cultivators. Severe problems will result in hill lands in many countries if the intense desire for land is not met in some realistic and equitable way.

Diseases and Hill Lands[1]

Both human and animal diseases may play a role in the use and pressure on hill lands. For example, the Terai of northern India and southern Nepal was formerly heavily infested with malaria, denying use of these lands and ensuring heavy populations in the hill country to the north. Control of malaria opened up the Terai to settlement by many land-hungry families in the hills. The hills in Nepal contain 31% of the cultivated land of the country and support 59% of the population. There are nine people per cultivated ha in the hills versus three per ha in the Terai. Hill farms are very small, 82% being less than 0.67 ha in size.

Malaria is not always a lowland disease; in some regions, notably in Indochina, hill areas have more malaria than lowlands. Also, hill area vectors such as *Anopheles pseudopunctipennis* in Latin America cause malaria at higher elevations. In Southeast Asia, heavy population pressures of coastal areas force people into hills, where they carry on shifting cultivation despite health limitations due to continuing pressure of disease. Crop production under these conditions will often be limited by the amount of the disease present. Studies in Thailand show that maize and rice production in hill lands is inversely related to levels of malaria there.

[1] Information for this section was obtained largely from personal communications with Dr. Lee Howard, Director of the Office of Health, Technical Assistant Bureau, Agency for International Development, Washington, D.C. 20523.

In Central America, higher populations live in the mountains than in the coastal lowlands, supposedly because of greater disease problems in the lowlands. In colonial times, many HT hill lands were used as resorts and rest areas for Europeans seeking respite from heat and sickness in the lowlands (Spencer and Thomas, 1948).

Coffee-producing areas have long been considered as healthful places. Rudolph (1944) quotes the common view in Latin America—"Wherever coffee grows, there it is healthy to live."

People in hill lands often suffer greatly from mal- or under-nutrition, and such deficiencies exacerbate existing problems of resource management and food production. This may be especially true in cases where adult males from hill areas migrate to lowland or coastal areas to seek employment, thus reducing further the opportunity to produce more food or to manage resources more effectively. Also, such migration tends to bring lowland diseases to hill areas where they did not exist before.

Dr. Howard[2] states, "The cultivation of hill lands sometimes produces ecological change in the lower areas which in turn produces an adverse effect on health at the lower elevations. A good example of this is the restricted area of prevalence of elephantiasis, a complication of filariasis, in the Serajoe River delta on the south coast of the Island of Java. Deforestation of the central mountain regions of the Island magnify the differences of water supply to the river during rainy and dry season. Torrential flow carrying silt and drift material, followed by a slow flow, close the river mouth in the dry season due to insufficient power of the river to force its way through surf and drift. This leads to the formation of lagoons. A network of lagoons and stagnant waters produced excellent breeding conditions for the transmission of filariasis."

A fruitful area for further study would be the influence of human health and nutritional factors on land use, especially in hill lands.

AGRICULTURAL POTENTIALS OF HT HILL LANDS

Despite generally favorable rainfall, HT hill lands are usually sparsely settled and less developed than adjacent lowlands. Man/land ratios are quite low in most HT hill lands in Africa and South America, but are much higher in some parts of Central America, the Caribbean, and Asia. Many factors relate to population patterns of these lands, including tribal or group customs, land tenure patterns, health problems, status of roads and transportation facilities, distance to and availability of markets, and educational opportunities. Agricultural productivity factors also strongly influence hill land use.

[2]See footnote 1.

HT lands often share several problems, notably; infertile soils, high cloud cover and resultant low solar radiation during the wet season (Chang, 1968), difficult topography, and a generally low standard of production because of the preponderance of subsistence farming as a livelihood.

A main advantage of HT hill lands is generally favorable rainfall which, in Af climates, is generally well-distributed throughout the year. Am climates, with a short to medium-term dry season, suffer from water shortage during during part of the year and often run short of feed for animals as well as food for humans.

There can be no doubt that some HT hill lands offer potential for development and higher productivity; the question must be, how can the high potential lands be identified and what management systems will be most suitable for sustained production? A related question must be, how can less suitable hill lands be retired from production and conserved for forest or watershed use?

CURRENT USE PATTERNS

HT hill lands are used today for many purposes (Table 2), including production of plantation and cash crops in both lowland (0–600 m) and upland (600–1 800 m) hills. Such crops are grown either on a large or small scale, depending upon the region and the resource base. Plantation and cash crops will be discussed in more detail later. These lands are also used for both large- and small-scale grazing.

A major agricultural use is for shifting cultivation or swidden-type agriculture, upon which perhaps as many as 200 million people in the world depend for sustenance. This system has aroused much controversy because it has contributed to denudation of forests and, in some areas, has caused significant degradation of the natural resource base.

Another use for those lands is for forests, both for native hardwoods as well as for national parks and watersheds. Many such lands have been set aside as wildlife or botanical reserves. Preservation of such reserves is increasingly difficult because of illegal poaching or hunting and pressure for land by squatters, plus normal food gathering activities.

Shifting Cultivation

Originally designed to build up soil fertility by allowing forest regeneration during very long fallow periods, 30–60 years or more, shifting cultivation is basically conservative and stable. However, high population pressure in many lands has caused fallow periods to become shorter and shorter, to the point that in many cases the length of the fallow barely exceeds the length of the cultivated period. Other major problems facing the shifting cultivator are increasing weed competition (especially by perennials); a rapid decline in soil fertility accelerated by

TABLE 2. Some basic farming system patterns of Humid Tropics hill lands

Farming System	Land Use Pattern	Basic Impact on Natural Resource Base[a]	Research Knowledge or Support Base	Major Commodity/ies, Crops	Secondary Commodity/ies, Crops	Major Cropping Pattern
1. Subsistence farming						
a. non-intensive	Usually shifting cultivation or very small subsistence farms coupled with shifting cultivation. Ratio of non-cultivated/cultivated land varies widely, 15–20 to 1	Conservative or exploitive (in some regions very exploitive)	Poor	Rice Corn Beans Cassava Yams Plantains Narcotics Coconut Banana Sweetpotato	Pulses Tropical fruits Root crops Coffee Stimulants Spices Goats Swine Few cattle or domestic buffalo	Mixed cropping, intercropping, usually uncontrolled grazing, or foraging by animals
b. intensive	Usually sedentary, usually small farms, could include some shifting cultivation in which ratio of non-cultivated/cultivated land is nearing 1:1	Can be exploitive or conservative, seldom optimizing because of lack of inputs	Poor	Rice Corn/beans Cassava Yams Plantain Banana Narcotics Coconut	Pulses Tropical fruits Root crops Coffee Stimulants Spices Goats Swine Few cattle or domestic buffalo	Mixed cropping, multiple cropping sometimes animals may be restrained
2. Commercial crops						
a. export crops, large scale systems	Usually intensive	Wide range, from exploitive to optimizing	Usually good. Research support by government or private sources	*Lowlands*[b] Sugarcane Coconut Cacao Rubber Banana Pineapple Oil palms *Upland*[b] Tea Coffee	Other species Tobacco Cinchona (in some areas, food crops are grown) Beef Dairy	Usually monocrop, may use cover crops, shade crops other aid crops
b. export crops, small scale systems	Usually intensive	Wide range, from exploitive to optimizing	May be good; usually depends upon status of the industry in the country. If mostly small farmers, support may be poor	*Lowlands* Sugarcane Coconut Cacao Banana Pineapple Cinnamon Spice crops Tobacco Oil palm *Uplands* Tea Coffee	Food crops Beef Dairy Fruit crops Swine Poultry	Usually intercropping, mixed cropping; seldom monocropping

[a] According to classification system proposed by Evenson, Plucknett, and Horton (1973).
[b] Lowlands = 0 to 600 m; uplands = 600 to 1 800 m.

shorter fallow periods and repeated burning; competition for land by squatters and landless laborers; and catch cropping by sedentary farmers.

Many shifting cultivators belong to tribes or cultural minorities, and many governments are perplexed as to how to control their activities without seriously endangering their livelihood or future welfare.

There is a real need to bring the benefits of scientific agriculture to the shifting cultivator (Greenland, 1976). Past efforts have been made, but with varying degrees of success. For HT hill lands, research must be coupled with better appraisal of land use potential, more adequate soil protection and conservation practices, and better watershed management systems (Pereira, 1973).

Plantation and Cash Crops

Much of the world production of the so-called tropical plantation crops or export crops is centered in the HT, and many of these crops are grown, at least in part, in hill lands. HT hill lands are ideally suited for growing perennial export crops. In many ways these crops are also "problem crops," and their prices fluctuate greatly on world markets, contributing greatly to economic instability in the producing areas.

"Lowland hill" plantation or export crops include sugarcane (*Saccharum officinarum*), coconut (*Cocos nucifera*), Hevea rubber (*Hevea brasiliensis*), banana (*Musa spp.*), abaca (*Musa textilis*), pineapple (*Ananas comosus*), African oil palm (*Elaeis guineensis*), cacao (*Theobroma cacao*), and cinnamon (*Cinnamomum zeylanicum*). "Upland hill" plantation or export crops include coffee (*Coffea spp.*), tea (*Camellia sinensis*), cinchona (*Cinchona spp.*) and exotic hardwoods such as teak (*Tectona grandis*) and mahogany.

Currently some export crops are suffering greatly because of a number of problems, including: poor world prices; serious competition from other crops (especially in abaca, sugarcane, pineapple); dominance of older, less productive stands which need replanting (especially true in coconut and tea); and attack by serious pests or diseases (notably coffee, coconut).

In many HT hill areas, efforts are being made to find alternative uses for lands previously devoted to plantation crops. Some of these lands, especially some areas planted for many years to tea, have also suffered from soil erosion because of difficulty in controlling weeds in the interrows without baring the soil to the heavy rains.

In the future export crops will likely continue to occupy a significant area of HT hill lands, because of generally favorable growing conditions, the opportunity to produce a cash crop with relatively small shipping volume and comparatively good price, and the availability of relatively cheap labor. However, it is also probable that marginal production areas will continue to seek agricultural diversification and alternate uses for the problem lands.

Sedentary Subsistence Farming Systems

Many HT hill farmers are sedentary, growing food and/or a combination of export and food crops. Farm size is small and family income and welfare are meager. Public transportation for either man or products is usually poor to non-existent. Marketing is difficult and is usually restricted to nearby centers for perishable products. For this reason, nonperishable income-producing products are sought. Such crops vary from copra, cacao beans, and smoked rubber to narcotic plant products such as the opium poppy or coca. Until some means can be found to introduce new crops with some income or market potential, the problems of low income, poor health and nutrition, and production of illegal crops will continue. The hills are difficult places in which to live, and their inhabitants will place highest priority on survival, notwithstanding the wishes of governments or more fortunate persons who are affected by their hill agricultural activities.

INFLUENCE OF HILL SOIL MANAGEMENT ON LOWLAND REGIONS

Activities in the hills of many lands cannot be disregarded, for they can profoundly affect the welfare and future of the lowlands below. These hills, if denuded or allowed to erode, can cause serious sedimentation of irrigation systems and streams below, rapid runoff of surface water, serious flooding, and can lead to reduced groundwater discharge (Pereira, 1973).

MAJOR PROBLEMS OF HT HILL LANDS

Deforestation and Land Denudation

A major problem of HT hill lands is rampant cutting and clearing of native forests (Eckholm, 1976a, 1976b). In part this has been caused by shifting cultivators in their search for land to grow food crops, but the quest by impoverished people for firewood and for wood to make charcoal has greatly accelerated the process.

Some countries have experienced severe cutting of forests which has led to extremely serious natural resource preservation problems. Haiti may be in most serious jeopardy, but Nepal and parts of Java are also facing great difficulty.

Major Weed Problems

Weed encroachment and invasion can greatly affect the way the hills are managed. Weeds, always a significant problem for the cultivator in the tropics, can be particularly difficult in HT hill lands, espe-

cially in systems where shifting cultivation, plantation crops, subsistence farming, or animal production on tropical pastures are major enterprises.

As has already been mentioned, perennial weeds, notably perennial grasses, are a major problem in shifting cultivation (Holm, *et al.*, 1977). Many perennial grasses are fire resistant and continue to build up high populations with repeated cutting and burning, thereby becoming the dominant vegetation of many HT hill lands. Once dominant, and in the presence of continued burning, heavy leaching of nutrients from ash and soil, and declining soil fertility, these lands become degraded, poor quality grasslands unfit even for satisfactory grazing. Grasses which predominate in such areas include: *Imperata cylindrica*, *Pennisetum polystachyon*, other *Pennisetum* species and *Saccharum spontaneum*.

The battle with perennial weeds causes great difficulty also for export or plantation crop systems, resulting in very significant land management problems. Such effects are too numerous to be detailed here, but perennial weeds which cause particular problems include: *Cyperus rotundus*, *Imperata cylindrica*, *Mikania cordata*, *Panicum maximum*, *Chromolaena odorata*, *Saccharum spontaneum*, and *Panicum repens*.

Small subsistence farmers have sometimes had to abandon lands and move their villages because of the invasion and perniciousness of weeds such as *Chromolaena ordorata* or *Imperata cylindrica*, and the names they have given them often reveal their revulsion and sense of despair. For example, in the South Pacific, *Mikania cordata* is known as "mile-a-minute," while in Nepal the local name for *Chromolaena odorata* means "forest killer." Unaided, small farmers often despair of ever controlling such plants and move on to clear more forest (and often to repeat the process) or on to the slums of the cities.

Weeds which take over and deny use of pastures include *Psidium guajava*, *Lantana camara*, *Trichachne insularis*, *Stachytarpheta spp.*, *Eupatorium spp.*, and many more.

Clearly weed control is and will be a significant management need for improved use of hill lands. Otherwise, the weary cycle of clearing of the forest, shorter and shorter periods of productive use for food or fodder, and eventual creation of weedy secondary forests or degraded grasslands will continue.

Erosion Hazards

No discussion of hill land production systems would be complete without a discussion of potential soil erosion. The Humid Tropics receive a great deal of rain, much of it in heavy downpours which can reach 150–200 mm or more in a 24-hour period. One question which might be asked is, are tropical soils less or more susceptible to erosion under heavy rains than temperate zone soils?

The soil loss equation is given as A = RKLSCP (Wischmeier and Smith, 1965), where:

A = computed soil loss per unit area
R = rainfall intensity and erosive potential
K = erodibility factor of a given soil
L = slope, length
S = slope gradient
C = cropping management
P = erosion control practices

A review of the several factors affecting soil loss will reveal that many of the factors are beyond the control of man; these are rainfall, inherent soil characters, and slope gradient (except where terracing or regrading is done). Factors which man can alter are: slope length, cultural practices, or specific erosion control practices. Reduction of slope length by piling field debris, rocks, and logs; cutting small contour channels; or building small contour bunds is certainly possible for most HT hill cultivators. Cultural practices which increase infiltration and reduce amount of bare soil exposed to high intensity rainfall is probably one of the most important management steps available.

One major question remains; just how erodable are tropical soils in the hills? Recent erosion studies in Hawaii revealed that K values for four soil orders increased in the sequence: Ultisol, Inceptisol, Oxisol, and Vertisol (Dangler, *et al.*, 1976). In these studies a wide range of K values was obtained, from 0 to 0.60 (Table 1). Wet soils were more subject to erosion than dry soils, owing to gradual weakening of soil aggregates after wetting and to greater runoff resulting from earlier attainment of soil saturation, and therefore low water intake rate. Soils derived from volcanic ash displayed a wide range of K values.

Soil Conservation Needs

Soil conservation and protection structures and practices should be evaluated, including:

a. terracing—bench, sloped, etc.
b. use of check dams, diversion ditches, control over waterways
c. contour cultivation
d. strip cropping
e. sod crops, cover crops, continuous soil covers
f. suitable legumes and soil-holding, soil-building crops
g. minimum tillage
h. protective mulches
i. revegetation of bare, eroded lands
j. building soil fertility
k. revegetation and management of strip-mined lands (bauxite, other ore-bearing hill lands)
l. pasture establishment and management
m. controlling unauthorized burning and cutting
n. inclusion of legumes in farming systems

DISCUSSION OF SPECIFIC CROPS

Plantation or Export Crops

Banana is commonly found throughout HT hill lands, mostly at elevations below 1 000 m. The crop is managed in several ways, from intensive, large-scale plantation production for export, to use in intercropping systems on subsistence farms (Simmonds, 1966). It can be the primary crop in intercropping systems or an intercrop.

Relatives of banana—abaca (*M. textilis*) and plantain (*M. paradisiaca*)—fit much the same role as banana in HT hill farming systems.

Banana cannot stand much weed competition; for that reason it is necessary to find satisfactory cover management which will provide weed control but which will not contribute to soil erosion.

Cacao is mainly a crop of the lowlands and is usually grown below 500 m; however, if temperatures are suitable, it can be grown at up to 1 000 m. Best growth is at about 200 to 300 m (Ochse *et al.*, 1961).

Cacao is often grown under shade or in intercropping systems (Urquhart, 1955). As with other tropical crops, weed control is important. Some farmers ring-weed around the trees and slash down weeds in the inter-rows. In shaded culture, weeds are less of a problem because of the shading by the heavy canopy.

Cinchona, a native of the highlands of South America (Taylor, 1945), has long been associated with HT hill lands. In its native habitat it is grown from about 900 to as high as 2 500 m or more. Mostly grown as a plantation crop, in Java it is grown at elevations of about 1 000 and 2 100 m.

Coconut is grown along the coasts and on peninsulas of the HT. It becomes a part of hill agriculture from near sea level to about 500 m near equatorial regions. About 90% of the world coconut lands are in Asia. Coconut is probably intercropped more than any other tree crop in the world. Hill systems include intercrops such as natural pastures, improved or cultivated pastures, cassava, abaca, edible aroids, maize, local fruit trees, other palms, many staple food crops, and even spice and condiments. Cover management on the land beneath the palms is always a problem, and ranges from frequent cultivation, occasional mowing or hand slashing and cover cropping to intercropping and pastures. Coconut hill lands comprise one of the most promising food production potentials of any HT hill lands, for they: (1) are close to markets and transportation, (2) usually lie close to population centers, and (3) are often found on some of the best lands of tropical countries.

Coffee is a traditional hill crop and has long been a source of income for hill farmers. Best quality coffee is produced at higher elevations—1 200–1 700 m in the best producing areas (Ochse *et al.*, 1961). Many people believe that coffee can only be grown on steep hillsides, but this is not correct, for good quality coffee is grown on level or near-level lands in Kenya and Brazil (Wellman, 1961). Coffee is often grown with shade crops; in these systems lower rates of fertilizers are usually used. Unshaded coffee can be grown successfully if fertilizers are used.

Weed control is a continuing problem, and there has been much work on finding satisfactory weed control methods which will also hold down soil erosion. Mulching has been used successfully in some areas.

Intercropping and mixed cropping are not common in coffee. However, some very interesting work on intercropping with plantains and papaya has been done in Puerto Rico by Jose Vicente-Chandler and his co-workers. *Xanthosoma sagittifolium* is shade-tolerant and can be grown as an intercropped food crop with coffee.

Oil palm is mainly a crop of coastal lowlands (Hartley, 1967), but is also grown in hill lands. In Malaysia where jungles are being cleared to plant the crop, bench terraces are constructed on hills to grow oil palm. The crop is mostly grown on a large scale, especially in Asia, and is seldom intercropped.

Rubber is basically a lowland crop, the best growth usually being obtained at elevations below 200 m (Polhamus, 1962). Above that elevation trees grow slowly; however, some higher sites have been successful because of favorable climatic conditions. In general, for each 200 m of elevation, tress take three to six months longer to reach tapping size (Ochse *et al.*, 1961).

Mostly a large-scale enterprise, rubber is seldom intercropped. Cover management to control weeds and prevent soil erosion is a major problem. The Rubber Research Institute of Malaya has been a leader in research on cover management.

Tea is another traditional hill-land crop. A cool climate crop, it can be grown at elevations of up to 1 000 m (Eden, 1965). Cloudy weather slows growth of the bushes. Weeds and cover management are always problems for the producer. Weeds must be controlled, but accomplishing this without causing soil erosion can be difficult. The objective used most frequently is to encourage growth of less competitive annual dicotyledons as a "living mulch" and to control perennial weeds. It is difficult to find alternate uses for marginal tea lands because of steep topography, generally low soil fertility and, sometimes, seriously eroded soils.

Teak is an exotic hardwood. Teak forests are highly prized and are carefully managed. Some teak is harvested from natural forests, some is planted and grown much like any other commercial crop (Mathur, 1973).

Food Crops

Rice. HT areas grow much of the world's rice, a large amount of it under lowland flooded conditions. However, the hills also are important rice-producing areas, mostly for upland rice, including flooded rice grown in bunded terraced lands set up to impound rain water, as well as in rainfed rice fields without bunds (IRRI, 1975). Vast areas of rice are grown under these systems, and a considerable proportion is grown in hill lands. Yields are very low, owing to infertile soils and intense weed competition.

Hill lands also include some small areas of irrigated rice grown with controlled water. Water sources may be from stream diversions or reservoirs.

In addition to being a source of water for irrigated rice, adjacent hills are important to rice farmers, some of whom also may cultivate some hill lands for catch crops, supplementary food crops, or for fodder.

Corn. Another basic cereal of HT hill lands is corn. In Central and South America, most corn is grown in mixed cropping systems with beans. In Africa, root crops such as cassava or "cocoyam" (*Xanthosoma sagittifolium*) are intercropped with corn. In Asia, corn is frequently grown as a sole crop in small hill fields.

The Tropical Root Crops. Root crops are basic staples of many farmers. Included are sweet potato (*Ipomoea batatas*), taro (*Colocasia esculenta*), yautia or cocoyam (*Xanthosoma sagittifolium*), various yams (*Dioscorea spp.*) and cassava (*Manihot esculenta*). Many of these crops are grown as intercrops. A noteworthy hill system is the sweet potato subsistence farming system in the highlands of New Guinea.

Other less well-known tropical root crops are *Alocasia macrorrhiza* and *Amorphophallus campanulatus*.

Pulse Crops. Many grain legumes are grown in the hills. Included are pigeon pea (*Cajanus cajan*), common beans (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), peanut (*Arachis hypogaea*), and others. Most are grown as intercrops.

Vegetables. A multiplicity of vegetables is grown in hill lands. Too numerous to enumerate, they range from multiple-purpose Leguminosae, leafy members of the Cruciferae, various Solanaceae, to various Cucurbitaceae. Probably more than 100 species of plants are used as vegetables in the tropics for edible leaves, fruits, seeds, pods, stems, etc. Vegetables are an important source of vitamins and minerals in subsistence diets. The Asian Vegetable Research and Development Center is working to develop suitable vegetables for HT lands.

Tropical Fruits. As with vegetables, many fruits are grown in HT hill lands. Many of these fruits are little-known outside their producing areas, but they provide variety and flavorful nutritional values to the diet, while yielding good income for farmers. Papaya, citrus of all kinds, avocado, mango, mangosteen, rambutan, lanzones, sweetsop, soursop are grown—many of these names are little known in the temperate zone, but they are important in their own right in HT hill lands.

Non-Food Crops

Hill lands are used to produce many other crops, including spices, condiments and other specialty crops.

SPECIAL NEEDS OF HT HILL LANDS

If HT hill lands are to be productively conserved for future generations, a number of measures, many of them interrelated, will be necessary. These include:

(a). Appropriate and adequate soil and water conservation and management practices to prevent soil erosion and declining fertility. Included will be measures such as terracing, cover cropping, cover management, strip cropping, minimum tillage, or other practices which can deal with heavy rainfall on steep lands. State-of-the-art studies to evaluate existing practices could help to inventory current knowledge (Plucknett, *et al.*, 1976). Also, research will be needed.

(b). Shifts in land use, including intensification of production on better lowlands, in order to reduce pressure on marginal or submarginal hills. To do this in some countries, especially those with high erosion hazard or very low soil fertility, may require land reform.

(c). Reforestation or revegetation of eroded areas or degraded grasslands with leguminous trees or other plants which can help to build soil fertility or can tolerate sub-optimal soil conditions. *Leucaena leucocephala*, a hardy tropical shrub or tree, has been used successfully for this purpose in Asia, notably in the Philippines and Indonesia.

(d). Alternate sources of firewood, charcoal wood, and in some cases, fodder or pasture will be needed to take pressure off already-denuded or degraded lands.

(e). Watershed management must be improved. Most countries should improve their capability in this area. State-of-the-art studies should be made now in order to bring together the pool of knowledge, published and in practice, on successful and unsuccessful measures and practices.

(f). For many countries, inventories of land use potential and land use classification and mapping.

(g). Special research centers or stations to serve hill land farmers more effectively. Special appropriations and resources will be required for many areas.

(h). For many areas, improved management of tropical pastures, especially where animal protein is needed, whether from meat or milk.

A SUGGESTED STRATEGY TO ASSIST HILL LAND—BASIC NEEDS

1. Mobilization and deployment of knowledge, both published and in practice, about management of hill lands.
2. Find ways to achieve technology transfer from one HT area to another.
3. Build and increase awareness of problems and opportunities for HT hill lands: for governments, community leaders, the public, and farmers.
4. National research inventories.

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DISCUSSION

Tanis (Haiti). In most of the papers about hill land improvement, it was impossible to make any kind of comparison between the developed countries and the developing countries. I will try to make some statements about the hill land in the tropics. I think it has been very difficult to solve this problem because so many factors are involved, such as lack of communication and literacy. Those governments in the developing countries are making a lot of effort to improve this situation, but they are facing so many problems that the efforts that have been made would present some drops of fresh water in the Pacific Ocean. Most of the hill people are not well aware of how to make improvements. In my opinion, most of these countries are facing a problem—erosion. Erosion is more and more becoming not only a national problem but an international one, and taking into consideration that the population of the planet as the end of this century will reach about 6 billion people, I think that this problem can not be solved on a national scale, but it is compulsory for all the developing countries to strengthen together their effort in order to solve it. I would like to have your opinion.

Plucknett. I couldn't agree more. Erosion is so severe and so serious in some countries that there isn't any question that something must be done. It's something for which you could not calculate a cost: benefit ratio, but it is imperative. There is no choice for many countries. It's either stop erosion or face further decline in the natural resource base at a time when population increases. How this is done is a very difficult problem. Most countries do not have enough governmental stability to be able to impose strictures that are necessary. We're not even applying the erosion control measures that we have now. It is a very difficult problem.

E. deVries (Pennsylvania, USA). I spent 23 years in Indonesia and you mentioned that lalanz or the

grass in the Phillipines covers 6 to 9 million ha, which is a surprisingly small area. There were 15 million ha of this grass in Indonesia before the war and the lastest estimate is about 40 million ha. FAO, before the Viet Nam War, estimated about 30 million ha in the MeKong River countries, so that enormous areas are involved and the individual cannot control it. Now, fortunately, and unfortunately, I'm also chairman of the Advisory Bureau for Tropical Agriculture located in The Hague where there are people with 30, 40, 50 years of experience on this kind of problem. I must say that we get no answer from anyone—not from FAO—not from the World Bank and the last thing that I hope now is that they got advice from IITA, where they are working on tropical agricultural systems in the international effort to do something. But apart from shading, as you say, quite rightly, can the grass be controlled? The rhizomes of these grasses are fire resistant. You did not mention specifically fire, which is the only tool that the peasant has to control shrubs and grasses and at the same time stop a great danger.

A variety of *Eupatorium odoratum*, discovered after WW II in Burma by prisoners of war and in West Java, controls nematodes, does not burn, and does not become a weed itself. In combination with some legume crops it controls weeds very effectively by smothering because it will never burn in the driest season or the driest climate, on the planaltos centrale in Brazil for instance, and it can control very effectively and at low cost. So my question to you and to this whole audience is: Why discover a new method when 25 years ago a method was described and nobody wants to follow it?

Plucknett. The Eupatorium system you mean. One of the reasons it hasn't been adopted is because it has become a serious weed in itself.

deVries. This variety blooms only one month a year.

Plucknett. I didn't know anything about the one that only blooms once in a year, but *Eupatorium odoratum* is a very serious weed in many parts of the world. I would like to say that I agree entirely with you that we can only take a farming systems approach or a cultural approach to management, for example, to control Imperata. It is one of those grasses that does not do well under shading and there is work going on in the Phillipines right now which looks very promising—using *Leucaena leucocephala* on degraded grassland. The giant Leucaena will grow to 60 to 80 feet in 7 or 8 years and shade out the Imperata. Imperata is a serious problem and it is very hard to control. There's no question that we need to use more mixed systems which will incorporate a legume that will give us a particular benefit in the system and also reduce weed growth. Centrosema is used very effectively in Malaysia, for example, for controlling weed growth in the early stages of rubber production.

Harold Barrows (USDA, USA). In your talk you mentioned the transportation system and also the marketing system. Do you have any figures that would give us any indication of the amount of losses that we get in the tropics before the food actually gets into the hands or the stomachs of the consumer?

Plucknett. No, I don't. This would be very hard to come up with. I guess it could be calculated if you could figure out how much the farmer produces, how much he and his family are able to transport on their heads or on their backs or on the backs of their animals to the nearest market, and then how much he's able to sell and how much is spoiled at the end of the day. It is very difficult. There is no question that there are serious losses; I think in many cases the amount of field area that a farmer does manage is entirely geared to the amount that he can market, that amount that he can actually physically carry to market. Just taking a look at what comes into the market is not enough because there must be a way of coming to grips with losses and problems back at farm level. It must be significant. If you go into most developing country markets, there is food for sale there but very often people aren't buying it because they haven't enough money. You usually don't see markets that do not have some food.

Dick Tinsley (Irri, Philippines). I'd like to comment on both questions that have been brought up. First, on the marketing of vegetables, one estimate that I had in Viet Nam was that between the transportation between Dalat to Saigon, about 50% losses were taking place. As far as the control of Imperata, I think in the Capiz province in the Philippines some farmers are actually trying to get some control on it by interplanting it with sugar cane. I don't know of any research on that; I just know that a couple of farmers' interviews indicated that they were able to get some control of the Imperata by planting sugar cane.

7.
Development and Use of Hill Lands for Intensive Agriculture in Sri Lanka

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The development and use of hill lands for intensive agriculture represents a comparatively recent venture in Sri Lanka, and dates back to the opening of the plantations by the British nearly one and a half centuries ago. Since then the hill country has contributed considerably towards the economic development of the country, and even today remains a major contributor to national income. The hill country in Sri Lanka comprises a central masif of hills, clearly marked out from the rest of the Island, which together form a distinct natural region (Fig. 1). The land everywhere is over 300 m above sea level, the highest section consisting of ranges between 1 500–2 100 m. It is drained by the head streams of several rivers, of which the Mahaweli ganga is the master stream. As the hill country is made up of a series of plateaus, rivers crossing them have to leap down from one plateau to another, and this accounts for the series of waterfalls found right round the hill country. The soils of the hill country are derived from crystalline igneous and gneissic rocks and consist mainly of deep lateritic loams. The mean annual rainfall, which is largely monsoonal, varies from 2 540–5 080 mm and the area is classified largely as a wet zone. The distribution of temperature is more or less controlled by the relief, isothermal lines being more or less coincident with the contour lines. The hill country is therefore generally cooler, the mean temperature being around 21° C at 1 000 m and 15° C at 2 000 m.

Sri Lanka's recorded history goes back over 2 500 years. The ancient Sinhalese, who were traditionally rice farmers, settled largely in the lowland dry zone and developed a flourishing tank-irrigated agriculture. They found little to attract them in the hill country. Only when conditions became difficult for them on the plains due either to invasions or the outbreak of malaria, did they move to the dry eastern half of the hills and the plateaus where they could cultivate paddy on neatly terraced fields. There were hardly any settlements above the 830 m contour line. The higher hills were either largely forested or consisted of grassy plains and the people had little or no use for these lands.

The development of intensive agriculture on the higher hills dates back to the time when the British gained control of the entire island in 1815. Earlier, the Dutch, who had ousted the Portuguese, had made certain sporadic attempts to establish plantations, first, cinnamon and later coffee, but their efforts were unsuccessful, particularly because coffee was found to thrive only at the higher elevations which were not under their control (Mills, 1933). This difficulty was overcome with the arrival of the British who gave every possible encouragement to coffee cultivation by abolishing the export duty on coffee in 1825, waiving the land tax on coffee plantations for a period of 12 years beginning in 1829, and by equalizing the duties on Ceylon and West Indian coffee in 1835. Ceylon coffee thus found itself in a highly competitive position due to these factors, and coffee cultivation soon began to attract the attention of foreign investors. So great was the interest in coffee production during this time that it is usual to refer to the developments in the early 1840's as the "coffee mania." The area under coffee expanded so rapidly that within about 30 years more than 121 200 ha of virgin jungle land had been cleared and planted to coffee. Coffee, a tree crop, was found to grow easily on the hill slopes. No terracing was necessary and jungle land now began to yield considerable returns. Once the success of coffee cultivation was assured there began a steady inflow of British capital into the plantations. The growth of the plantations accelerated as the system of roads and railways developed. The construction of roads was necessary primarily to transport the produce which was mainly for export. By 1860 more than 4 820 km of roads had been constructed to cover largely the coffee plantations. This represents a substantial achievement when it is remembered that these were in the hill country running along steep gradients and crossing innumerable streams and rivers. The first railway connecting Colombo, the capital, with Kandy, in the hills, was completed in 1867 and this was extended to Nanu Oya in the higher hills by 1885.

The rapid expansion of coffee cultivation also led to a greatly increased demand for land and labor, and had an unsettling effect on the traditional village economy. In its anxiety to foster the growth of the coffee industry the government of the day also embarked on a land sales policy which had the effect of depriving the peasants of their traditional chena

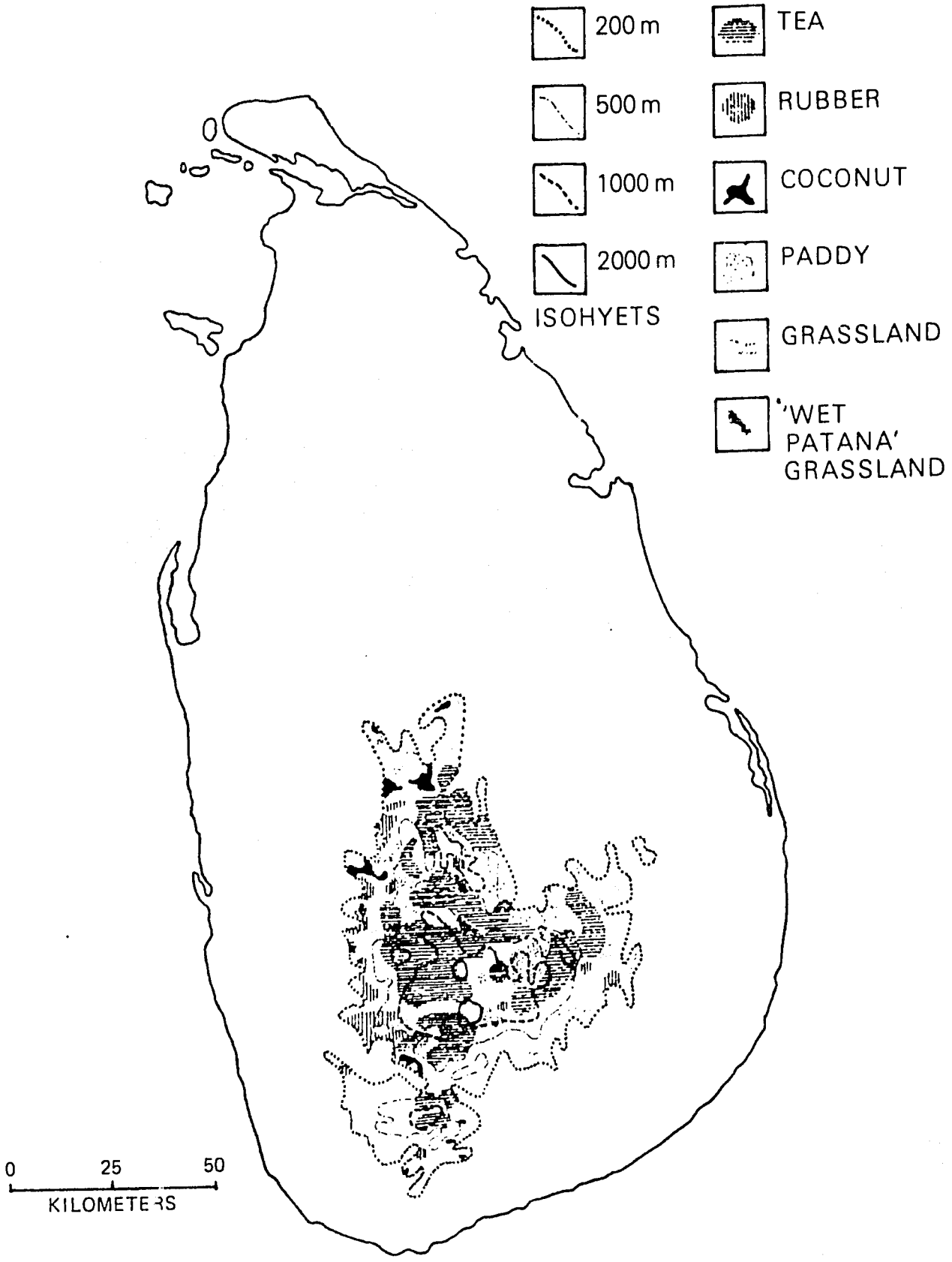

Figure 1. Relief map of Sri Lanka showing land utilization in the hill country.

lands, i.e., jungle land used for shifting cultivation, and the peasants were left only with the valley bottoms in which to eke out an existence. The indiscriminate felling of forests also led to a good deal of soil erosion and the silting up of tanks and rivers thereby impoverishing the peasants further. Many of them took the easy way out and sold their lands to the plantations. This created a class of landless peasants. Many of the present-day problems of poverty and landlessness among the Kandyan peasantry can thus be traced to the opening of the plantations (Jogaratnam, 1964). This was the first stage of the development of the higher hills. The coffee industry reached the height of its development in 1870, but crashed soon after due to the devastation of the plantations by the coffee blight.

In the frantic search for new crops the planters came upon two, tea and rubber. Tea, which occupied scarcely 400 ha in 1875, expanded so rapidly that by 1900 nearly 162 000 ha had been developed. Rubber was introduced around 1900 but within 25 years it too had come to occupy another 162 000 ha. Thus, within a period of about 100 years, more than 405 000 ha of jungle land had been developed and brought under plantation crops in the hills. This had been achieved by the large-scale inflow of foreign capital and foreign labor (imported labor from South India). The spread of the plantation system with its emphasis on large-scale methods of cultivation, heavy use of capital and labor and production primarily for export had completely overwhelmed a self-contained, rice-oriented village economy.

Today, nearly 110 years after the first commercial planting of tea, that industry has developed into one of the best organized in the country, the principal earner of foreign exchange and a major contributor to our national income. The total area under tea at present is estimated to be around 243 000 ha. Nearly 2/3 of this is in the higher elevations where whole stretches of the hill country are covered with this crop. Since climate has a marked effect on the quality of the final product, although a broad contrast is made between the low country and the hills, a distinction is commonly made among teas grown in the three elevational zones, i.e., low-grown (sea level to 600 m), medium-grown (600–1 200 m) and high-grown (over 1 200 m). Approximately 25% of the total tea area is low-grown, 39% medium-grown and 36% high-grown. Tea plantations in Sri Lanka also have been traditionally classified by planting districts, a term which came into being as early as 1856 when the existing coffee areas were defined using either large rivers or well-known mountain ranges as boundaries. There were 46 such planting districts and sometime teas of particular type or quality are identified on the basis of these planting districts.

Until the introduction of land reforms in 1972 and the nationalization of foreign-owned estates in 1975, foreign interests owned about 1/3 of the area producing tea. Of the 2/3rds balance, about 52% was in the hands of rupee companies. Most of these estates are economically productive units and it has been claimed that some of these estates are among the best run agricultural properties in the world. Production depends on a number of factors such as soil, variety, elevation, manuring, etc., but a major factor in increasing yields is better methods of cultivation and bush management and the use of nitrogenous fertilizers. Vegetative propagation of tea has also resulted in the selection of clones with a high yield potential amounting to nearly 3 400 kg of made tea per ha in the hill country. These are being used to replace seedling plantations which comprise 2/3 of the total tea area and are between 80–90 years old.

Small holdings of tea, on the other hand, which account for nearly 17% of the total tea area and consist of 4 ha units or less, are located mostly in the lower elevational zones. The majority of these contain barely 2 500 tea bushes per ha (optimum density 10–12 500) and a good many of them are no more than village gardens with a mixture of other crops such as cocoa, arecanut and jak. Generally as a result of the failure of small holders to adopt improved cultivation methods and the resultant erosion, the soils of many small holdings are now in a condition unfavorable to reasonable productivity. Since 1959 the government has attempted to improve the productivity of tea plantations through a tea replanting subsidy scheme for estates of over 40 ha, and a rehabilitating scheme for improving the agricultural condition of tea lands by the application of fertilizer, adoption of soil conservation measures and the planting of vacant plots on estates of less than 40 ha. For re-planting the target set was 2 000 ha annually.

New tea plants cannot be established until the soil has been rehabilitated after the old tea bushes have been uprooted, and this is done usually by planting Gautemala (*Tripsacum laxum*) or other similar grass for periods of 1–2 years. In preparing land for tea planting the three essential requirements are adequate protection from erosion, good preliminary cultivation to permit proper root growth and development of adequate shade to protect both the soil and the young growing plant. The construction of reverse slope drains is also commonly practiced in Sri Lanka. The earlier method of planting tea in lines up and down the hill was so disastrous that it was replaced by contour planting.

Tea is a labor intensive crop. Cultivation operations on tea lands are done by manual labor and so generally a regular labor force is employed on tea plantations. The labor requirement is approximately 2.5 units per ha, and this is particularly

advantageous in a developing country like Sri Lanka where the rate of unemployment among the young (15–24 age group) is over 40%. Mechanical methods of cultivation, though possible, particularly with the development of clonal material and slope pruning, is in fact unnecessary and might even be harmful in these circumstances.

Rubber was introduced into Sri Lanka with the turn of the century, and British capital was largely responsible for the opening up of these plantations as well, following the coffee crash. Rubber production is limited to the wet zone because of climatic restrictions, so that it is confined to the lands of low and medium elevation (600 m) in areas which come under the 3 175 mm rainfall isoheyt. Seedling rubber raised in nurseries is planted out in new clearings when the plants are about 18–24 months old, at spacings generally between 7.2 × 3.6 m. Tapping generally commences at 6 to 7 years of age and the output is maintained at economic levels for another 25 years. The total area under rubber in Sri Lanka is generally around 230 000 ha. The rubber replanting subsidy scheme was introduced in 1953, for replanting the old worn out rubber with budded high-yielding clones. Rubber production increased steadily due to this scheme and by 1971, 129 600 ha out of the total of 230 000 ha consisted of replanted rubber. Small holders' rubber occupies a more significant position in the rubber industry than small holders' tea in the tea industry. The yield per replanted ha is approximately 1 000 kg compared to old rubber lands where the yield was only 550 kg/ha. Rubber cultivation on an estate basis employs 1 labor unit per ha. On this basis the total employment through rubber cultivation in Sri Lanka is about 230 000 persons. Sri Lanka's rubber production, unlike that of tea, is only a minor part of world natural rubber production and varies from about 5–6% of world production (see Table 1 for comparative figures on tea and rubber production).

AGRICULTURAL DIVERSIFICATION ON UNECONOMIC TEA AND RUBBER LANDS

The Tea Commission in 1968, after examining recent developments in the world tea economy, suggested that market forces would sooner or later determine what areas would eventually have to go out of tea production in Sri Lanka (Tea Commission, 1968). This would include not only marginally uneconomic areas but also areas surplus to our requirements. The advent of vegetatively propagated clonal teas with high-yield potential and the advance of technology had clearly demonstrated that Sri Lanka could produce all the tea she needed on nearly 1/3 of the total land area now devoted to tea. Further, high-grown teas fetch premium prices in the world market and hence this called for a greater concentrated effort at the higher elevations. The remaining 2/3 of the tea area, mostly at medium elevations, could then profitably be diverted to the production of alternative crops. Rapid increases in human population had also resulted in strong pressures on available land resources for the cultivation of food and cash crops that could enhance the economic well being of the population in the area.

TABLE 1. Some comparative data on tea and rubber production, two major crops of the hill country of Sri Lanka—1974

Product	Area (1 000 ha)	Total Output (1 000 MT)	Exports (1 000 MT)	Value of Exports (Million Rupees)	Employment† (Thousands)
Tea	242.2	204.1	175.5	1 360	606
Rubber	228.0	136.5	128.4	738	196

Source: Report of the Central Bank, Sri Lanka.
†Estimated.

The choice of alternative crops would be determined by (a) the adaptability of the crop to the ecological conditions obtaining on tea land, (b) profitability—particularly a regular short-term income, and (c) its potential for earning or saving foreign exchange. Several promising crops satisfy these criteria, and among these special mention must be made of the following for which a fair amount of experimental evidence and experience with the crops is already available in Sri Lanka.

1. Coconut Palm. Experience with the coconut palm, which is Sri Lanka's third most important plantation crop, shows that although it grows best near the sea, it can be raised successfully up to an elevation of 450 m with a well-distributed rainfall from 1 520–2 280 mm. There is thus the possibility of replacing tea with this crop, and the tea small holder may well convert his tea plantation to a coconut plantation. Well-managed coconut plantations can give an average yield of over 7 500 nuts per ha, though yields of 12 500 to 15 000 nuts per ha have been attained on adequately fertilized plantations.

Even more attractive is the possibility of intercropping coconut lands, particularly with pasture. Sri Lanka is a pioneer in the field of intercropping and there is adequate experimental evidence to support the establishment and management of species such as *Brachiaria miliformis, Brachiaria brizantha* and *Digitaria decumbens* under coconut for the raising of both cattle and sheep. Intercropping with pasture is particularly successful in areas receiving at least 2 160 mm of rainfall, and the results of long-term experiments suggest that this association is in fact beneficial to the coconut palms (Santhirasegaram, 1956).

2. Cacao. Cacao (*Theobroma cacao*) was first introduced into Sri Lanka by the Dutch. The crop can be successfully grown at elevations of between 150–450 m with an average rainfall of between 1 520 to 2 000 mm. At present there are about 20 000 ha mainly in the mid-country. The main varieties are Trinitario and Amellanado. To the small producer of tea, cacao is a very suitable alternative crop. It is easy to process without expensive equipment. With an ever expanding export market, cacao should offer attractive possibilities on uneconomic tea lands.

3. Coffee. The return to coffee cultivation also has been advocated. Coffee had earlier reigned supreme on the hill sides of Sri Lanka, but later succumbed to a leaf disease. There is thus a strong case for the reintroduction of coffee, particularly the resistant robusta coffee at elevations below 600 m, though in fact the higher hills (900–1 800) are capable of producing the finest coffee of the arabica variety. At present there are only about 1 600 ha of coffee in Sri Lanka. Though the export possibilities for coffee are somewhat limited due to the operation of the international coffee agreement, there is still considerable scope for an expanded crop area to meet the domestic demand which is steadily rising. The processing of coffee beans is again a simple process well within the capacity of the small holder.

4. Pepper. Pepper is a creeper requiring moist heat with shade and an evenly distributed rainfall and thrives on artificial supports up to an elevation of about 600 m. It is usually raised economically on the shade trees planted for tea. Vines come into full bearing in the sixth or seventh year. Pepper is an important foreign exchange earner and ranks third in value in the internationally traded spices. There is thus considerable scope for the expansion of pepper on the hill sides in the mid-country of Sri Lanka.

5. Cloves and Nutmeg. Cloves and nutmeg are tree crops that thrive well on the undulating lands of the mid-country of Sri Lanka at an elevation of 300–600 m. The economic life of the trees is about 30 years. Although both are slow growing and do not come into bearing until they are about 8 years old, they are potential earners of foreign exchange. The FAO report of 1962 forecast that "supplies of nutmeg and mace will inevitably be scarce and the prices will be high," and this has been true. Those areas that are not unduly pressed for immediate returns can thus be profitably diverted to these crops.

6. Fodder and Pasture. For sometime now the focus has been on fodder development for increasing grassland productivity on the marginal plantations in central Sri Lanka. Here the lands are mostly undulating or steeply sloping, so that fodder grass development for zero grazing offers the greatest opportunity for maximizing grassland productivity. Fodder grasses are all high-yielding grasses, capable of supporting intensive animal production. Fortunately the climate of the hill country is suitable for both livestock and fodder. Rainfall is adequate to support herbage growth throughout the year. Better types of animals can also be reared because of the milder climate. There can also be no doubt that improved fodder species will restore these eroded hill sides to a high level of fertility and enable them to be utilized for more profitable crops at some future date if the need arises. Fodder grasses can be organized very efficiently on plantations in small holdings of 5 to 10 ha in which the development of the fodder will involve not only the planting, replanting, fertilizing and maintenance of the fields, but also the daily routine of cutting and transporting the cut fodder for the stalled cattle. Dairy units organized on this basis would be capable of generating employment which in its labor intensiveness would be second only to tea. The performance of three fodder grasses at Peradeniya in the mid-country wet zone of Sri Lanka indicates that yields averaging 43 222 kg/ha in the case of Pusa Giant Napier, 33 226 kg/ha with Guinea B (*Panicum maximum*) and 33 247 kg/ha with *Setaria sphacelata*, respectively, can be obtained when fertilized at the rate of 336 kg/ha N per year and cut monthly. Nitrogen efficiency of Pusa Giant Napier, which is a hybrid fodder derived from a cross between ordinary Napier (*Pennisetum purpureum*) and the annual millet (*Pennisetum typhoideum*) was 1:70 compared to two well-known grazing grasses *Brachiaria brizantha* and *Brachiaria ruziziensis*, which had efficiencies of 1:29 and 1:39 respectively (Appadurai 1973). It is clear that a grassland oriented agriculture on some of the marginal plantations in the hill country of Sri Lanka will not only expand the effective land area, but will give high yields of human food and effect considerable savings in foreign exchange now expended on the import of milk and meat.

These and other similar observations led primarily to the establishment of a UNDP/FAO-assisted project for agricultural diversification on the marginal plantations on hill lands, and quite logically the project was widened in scope to cover both the uneconomic tea as well as rubber lands. The major objective of the project was land use adjustments on hill lands in order to make them economically viable units. One of the first tasks of the project was to draw a distinction between tea and rubber lands that were unprofitable as against those that were uneconomic. In the first category were included all lands which, for various physical reasons, were unable to produce yields that would give a gross return large enough to cover costs and yield a profit under a specific price-cost situation with normal management practices. In the latter category were included all lands that would produce a higher gross

return if they were used for crops other than tea and rubber (Ministry of Plantation Industries, 1973).

Before deciding on the alternate crops that could be recommended on the tea and rubber lands the project undertook the necessary land and soil investigations in three stages (a) land capability surveys, (b) land evaluation surveys and (c) site evaluations. For the land capability survey, maps based on 1/25 000 aerial photographs showing soil phases such as slope, depth, rockiness and stoniness were used. Land classes were delineated on 16 chain sheet, (7.9 cm to the km or scale 1/12 672). These maps were adequate to decide on the kinds of cultivation to be practiced on these lands. In order to decide which specific crop could be grown on these lands, however, a land evaluation survey was undertaken which considered in addition, the climate, physiography, nature of the soil and the necessary measures to develop the land. This also gave an idea of the agricultural potential of the land after improvement and development.

Catchment Basin Development. As part of the land evaluation survey the soils section of the agricultural diversification project demarcated the wet zone of Sri Lanka into 47 natural regions which were termed morpho-ecological regions. Most of these are located in the hill country and can be further subdivided into smaller natural units defined by the catchment boundaries of the major streams. The agricultural diversification project has used the catchment basin as its planning unit for agricultural development. The development of the Nilambe oya-Atabage oya catchment basin (18 300 ha) and the Gurugoda-Ritigaha catchment (12 600 ha) in the mid-country of Sri Lanka are examples of such a development plan (Table 2). Since tea and rubber are uneconomic in the above catchments, the plan eventually envisages the diversification of these lands into other uses. The concept is not in terms of piecemeal diversification on individual plantations, but in terms of integrated development for whole catchments. Tea and rubber will be maintained on specific zones of the catchments and will be totally replaced in the others with alternate crops. The principal alternate uses for tea and rubber lands in these areas will be for animal husbandry, forestry and settlement farming; the major objective being the urgent need for soil conservation and rehabilitation of the area.

In working out its development plan for settlement farming, the project made a detailed study of the existing forest garden farms in the hill country which from the point of view of land use on hill slopes must be considered to be relatively efficient. The land cover provided by this traditional system ensures reasonable soil protection at very low capital cost. The high density of tree cover and resultant leaf litter, together with the minimum amount of weeding required favor soil conservation unlike tea lands where regular manual weeding accelerates soil erosion. The traditional forest garden mix already contains most of the alternate crops recommended—e.g., cloves, nutmeg, pepper, cacao and coffee. The usual extension problems of converting skeptical farmers to new crops does not therefore arise; what is required is a concentrated effort to improve cultural practices, such as proper spacing, fertilizer use, reduction of shade etc., which should be a much easier task. Since the mix also includes economic cash crops as well as subsistence produce, income levels would be decidedly superior to small holdings of either tea or rubber. It is precisely for these reasons that settlement farming based on these forest mixed gardens is being woven into the structure of integrated agricultural development within a catchment basin. Demonstration dairy farms, pilot sericulture projects and several other new land use adjustments are being worked into these development plans; and have already shown considerable promise. Forestry activities in the past, for example, have been devoted mainly to the planting of *Eucalyptus grandis* and *Gravellia robusta* for fuel on some of the larger

TABLE 2. Proposed land use adjustments on two catchments in the hill country of Sri Lanka

Crop	Present Area (ha)	Area Scheduled by Year 5 (ha)	Change (%)	Remarks
Tea	14 712	5 253	−64	
Rubber	4 079	3 256	−20	
Cardamom	413	817	+98	
Mixed forest gardens	5 784	13 005	+125	
Pasture	40.5	1 517		
Paddy	1 558	1 558	no change	
Eucalyptus	—	672	—	Fuel
Pinus caribaea	—	2 178	—	Timber and wood pulp
Conservation forestry	—	1 131		
Patana (grassland) and scrub	2 801	—	−68	
Jungle and forest	2 138	405		405 ha jungle to be planted with cardamom yrs. 6–10
Others	—	2 177	—	
Sericulture	109	69	−37	
Building land	—	55		Proposed new development

Source: Agricultural Diversification Project, Ministry of Plantation Industries, Sri Lanka

estates. Existing plantations indicate that these species grow well in the catchments and average yields of 18 m^3/ha could be expected. *Pinus carabaea* was introduced to the catchments as recently as 1972, and has shown considerable promise. The aim now is to bring the forest areas of the catchments into a productive state to conserve the soil and water resources of the catchments and to provide timber, pulpwood and fuel. It is envisaged that the full implementation of the project will take another 15 years or so. Given the resources and the will to do so, there can be no doubt that this will lead to a stable agriculture on these hitherto uneconomic hill lands.

THE HILL GRASSLANDS

Next to the plantations, the grasslands of the hills, locally known as the "Patanas," occupy a prominent position, extending in altitude from 450 m to the highest elevations (2 250 m). These grasslands cover an area of around 65 000 ha, and constitute an important potential resource in the development of the hill lands of Sri Lanka. Broadly they consist of two distinct communities, the dry and the wet patanas. The majority of the patana flora tend to exhibit strongly xerophytic features. Generally in the dry patanas, which occupy nearly 9/10 of the total area, this may be attributed to climate, while in the wet patanas it may be due largely to soil conditions, particularly a black, highly acid, peaty A horizon inducing physiological dryness. Several workers have tried to elucidate the origin of these grasslands and attributed their origin variously to the transformation of primary jungle by the regular and periodic felling and firing for purposes of shifting cultivation by man, the severe dessicating winds in the dry patana area leading to intense evapotranspiration which prevents the growth of trees, permanent soil degradation resulting from the abandonment of old coffee plantations and the upsetting of the man-land ratio during early British times with the opening of the plantations. Traditionally the patanas have been used by the grazier, who resorts to burning just prior to the rains in order to provide fresh succulent pasturage for his herd of cattle and buffalo. Sometimes this practice has led to severe sheet erosion. The problem is less severe on the wet patanas, most of which have been successfully planted with the highly productive kikuyu grass (*Pennisetum clandestimum*). Kikuyu has proved itself on these lands, even under conditions of heavy grazing. Two major cattle farms, with temperate breeds, have been established on nearly 4 000 ha of kikuyu at elevations ranging from 1 500–1 800 m. At these high elevations kikuyu produces high yields of crude protein, particularly when fertilized with high N, but runs into problems of low energy. Continuous cloudy weather in the higher hills may be a contributory factor. Climatic factors are more limiting, however, on the dry patana grasslands. While temperature regimes are suitable for the growth of tropical as well as subtropical species, soil moisture levels restrict growth mainly from June to September. The agricultural potential of the region is also determined by its topography, since the generally steep slopes and the high rainfall during the monsoon season pre-dispose the area to severe erosion. Accordingly, forestry and permanent grassland farming constitute the only feasible form of agriculture on these slopes. In the development of these lands afforestation has been undertaken in the form of shelter belts and wind breaks which could retard the effects of the strong dry winds in the area. Experimental evidence suggests also that the interpolation of a brief fertility re-building, pioneer-crop phase using sunnhemp and sorghum between the plowing up of the native grasslands and the establishment of superior pasture could constitute a possible method of circumventing the otherwise slow rate of establishment that occurs when superior pastures are planted directly on plowed land. Tropical and subtropical grasses such as the Panicums, Paspalums and the Setarias have been particularly outstanding in this regard. (Sivasupiramaniam *et al.*, 1973). Based on these studies the animal production potential of these hitherto uneconomic lands is currently being investigated, together with certain socio-economic aspects. These pasture investigations will then be used along with the socio-economic data to secure, quantify, synthesize and apply information for the purpose of future development of these lands.

Finally, Sri Lanka has witnessed during the last few years major changes in its agrarian scene. The nationalization of most of the hill lands under the land reform laws of 1972 and 1975 has given the country a unique opportunity to improve or transform uneconomic tea and rubber lands to the best economic and social advantage. Several types of new settlements are being worked out as a natural extension of the Agricultural Diversification Program. It is our sincere belief that the increased productivity that will result from such land use adjustments will ultimately generate both income and employment and will contribute to improving the quality of life for our people.

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DISCUSSION

Unidentified. Do you have a government policy to limit mechanization?

Appadurai. In developing countries like ours, it is government policy to adopt labor intensive methods in order to deal with unemployment. I think I said in my paper that there was over 40% unemployment in the 15-24-age group. With rapidly increasing population and rates of unemployment, I think that it is essential that we adopt this as a conscious policy.

Rodale Press. This is now a policy of your government?

Appadurai. Yes, certainly.

Alex Tanis (Haiti). In all of these developing countries, as it was stated previously, in order to improve the utilization of hill land we have to deal with many factors such as agricultural resources, lack of communication, lack of credit, lack of qualified technicians in order to do the job, and also lack of extension and research and training of the personnel. We notice that progress has been made to some extent by the government of Sri Lanka, but do you believe that it is possible on a larger scale in other regions of the globe? More and more, there is a greater gap between the prices of agricultural commodities coming from the developing countries and the prices of material and equipment, and also the fertilizers, to buy from the developing countries. Do you believe that it is possible for all the developing nations to follow the example of the government of Sri Lanka, and also do you see a way in which you can match, in a very small way, the opposing factors that I mentioned?

Appadurai. I'll come to the last part of your statement first. We embarked upon a policy of diversification of the kind that I was describing, because we were faced with the same problem. Our main export products are tea, rubber, and coconut. These always face problems in the world market because we cannot dictate terms and, faced with the problem of declining prices and a very high import bill on food in which we are not at all self-sufficient, we have to think in terms of diversifying our agricultural activities as a measure of import substitution. Fortunately, we had reached a point, a certain degree of competence, in the cultivation of tea and we have developed clones which could produce very much higher yields than we used to obtain so that we could cultivate tea on probably 1/3 of the tea area and then put the rest of the tea area to the production of other crops. We have had free education in the country from kindergarten through the university for the last 25 years. This has been a great advantage. The standard of literacy in Sri Lanka is perhaps the highest in Asia—we have almost 90% literacy. This means that extension techniques can probably reach most farmers a little more effectively. There is a concerted effort on the part of our government to consciously move the people to overcome the problems of high dependence on certain types of products and to diversify into other areas so that we can overcome the serious balance of payment problems that we have in the country. I think that when you have a lot of people on the land, you can achieve a lot in just using the resources that you have. In fact, if I were to put it this way, the development strategy in Sri Lanka in the past five years, say, has been to concentrate on the resources that are available to us. We certainly have a balance of payments problem. We don't have foreign exchange for the import of capital equipment and perhaps even fertilizers, but we have two major resources—land and people. So government has embarked on a policy of land reform which involves the use of their available resources in order to promote agricultural diversification and the use of labor intensive technologies. The concentration has been on small sector agriculture because small farms distributed throughout the country can produce effectively without a very high capital investment. This is the philosophy that we have been following and we hope that it will succeed.

8.
Intensive Crop and Animal Production Systems in the Tropical Hill Lands of Puerto Rico

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Much of the world's hunger is concentrated in the humid tropics, where there are hundreds of millions of ha of rolling to steep Ultisols and Oxisols which have excellent physical condition but are acid and low in fertility. Puerto Rico's mountain region is a good example of a region with heavy population pressure demanding an intensive agriculture on such lands.

This paper describes what can be done with intensive management systems on tropical hill lands where land is expensive, population pressure heavy, and the economy is developing rapidly. Although not typical of the tropics in general, such conditions do exist in many, but limited, areas and will become increasingly prevalent as the economy of the tropical countries develops.

The research summarized here was focused on developing complete systems of intensive management practices for producing high yields of crops that are soil protective, like pastures, or can be grown in such a way as to be soil conserving, like coffee. These systems were tested in commercial plantings to determine their practical and economic viability. This testing pointed out problems that helped to keep the research program on target and proved invaluable in extending results to other farms.

Unless otherwise specified all research was conducted on Ultisols or Oxisols containing about 3.5% organic matter with a pH of about 4.8 and a bulk density of 1.1. Annual rainfall averaged 1 600 mm and was fairly well distributed, except for a January to March dry season. Mean annual temperature was 25° C with seasonal variations of about 5° C. Minimum daily temperatures were rarely below 18° C and maximums rarely above 33° C.

SOIL FERTILITY, ACIDITY, AND EROSION

Ultisols and Oxisols are usually low in P, since the primary minerals are low in this nutrient. In Puerto Rico, these soils supply about 100 kg of N/ha/yr to grasses (Vicente-Chandler *et al.*, 1974) and a study to determine the amounts of K supplied by six Oxisols and 17 Ultisols to Pangola grass showed that after the first year the Oxisols supplied about 50 kg of K/ha/yr and the Ultisols about 90 kg of K/ha/yr.

In the humid tropics intensively managed crops can produce high yields with correspondingly high demands for nutrients. Moderately fertilized grasses removed 350, 70, and 400 kg/ha/yr of N, P, and K, respectively (Vicente-Chandler *et al.*, 1974).

With this low fertility and the high nutrient requirements of intensively managed crops, Ultisols and Oxisols in an intensive agricultural system can be regarded essentially as a rooting medium that provides anchorage and holds available moisture and applied nutrients for use by the plants.

Ultisols and Oxisols are also naturally acid with high contents of exchangeable Al, which impedes root growth and limits crop yields, or Mn, which is toxic to some plants. Crops vary widely in their tolerance to high soil Al and Mn levels. For example, coffee growing on an acid Ultisol high in exchangeable Al did not respond to liming but yields were tripled by liming on an acid Oxisol high in Mn (Vicente-Chandler *et al.*, 1969). Plantains, however, did not respond to liming on either an Ultisol high in exchangeable Al or on an Oxisol high in Mn.[1] Soybeans, corn, and green beans, however, responded strongly to liming on an Ultisol high in exchangeable Al (Abruña *et al.*, 1974). With all three crops, high yields were obtained when Oxisols or Ultisols were limed to above pH 5.2, at which levels there was essentially no exchangeable Al or Mn in the soil.

Ultisols and Oxisols are usually erosion resistant. Simulated rainfall at 6.4 cm/hr for 60 min. followed 10 min. later by 12.7 cm/hr for 60 min. on an Ultisol with a 30% slope resulted in a final infiltration rate of 3.7 cm/hr and soil losses of 0.87 and 5.12 MT/ha for the first and second rainfall applications, respectively (Barnett *et al.*, 1972).

Soil losses from an Oxisol with a 45% slope and 1 840 mm/yr of rainfall were 283, 40 and 5 MT/ha/yr when the soil was in fallow, a crop rotation and grasses, respectively (Smith and Abruña, 1955).

Both these soils, typical of vast areas in the humid tropics, were two to three times more resistant to erosion than Southeastern U.S. soils.

[1]Unpublished report by Fernando Abruña and José Vicente-Chandler.

Tilling steep Ultisols and Oxisols of excellent physical condition is often unnecessary, expensive and can increase erosion. The effect of complete land preparation as compared with no tillage of three typical Ultisols and Oxisols, with weeds controlled in both, resulted in similar yields of different crops as summarized in the following table (Vicente-Chandler *et al.*, 1966):

Crop	Average yields (kg/ha) Complete land preparation	No tillage
Plantains	20160	18820
Taniers	11310	11420
Yams	13330	12150
Corn	5260	5150
Greenbeans	3920	3820

Deep Ultisols and Oxisols generally have good physical condition throughout the profile and can be benched. Bench construction requires much human labor or costly equipment although such construction can also be accomplished gradually by plowing against contour grass barriers (Vicente-Chandler and Smith, 1951). Other less complex erosion control measures, like contour ditches and vegetative barriers, can also be used.

However, the most practical way to obtain proper soil and water conservation plus economic production on hill lands in the humid tropics is to grow soil protective crops such as grasses or those which can be managed so as to assure proper conservation such as coffee and other tree crops, and to manage them intensively to obtain high yields and income.

INTENSIVELY MANAGED GRASSLANDS

Grasslands are soil conserving and can be "mechanized" on steep lands by applying herbicides, seed, lime, and fertilizer with planes, helicopters or broad-base tractors. Grazing cattle can harvest the forage almost as effectively as they can on level

Figure 1. An intensively managed hill land farm in Puerto Rico. Intensively managed grass pastures in foreground carry five heifers/ha gaining over 1000 kg/ha yearly. Intensively managed, sun grown coffee in background harvested with nets yields more than 2000 kg/ha of market coffee. Note excellent soil protection afforded by the grass and the free growing coffee trees which are essentially a woodland since no pruning is practiced.

Figure 2. Intensively managed grass pastures in the hill lands of Puerto Rico carry five head/ha of beef cattle producing over 1 000 kg/ha/yr of gain in weight or two cows producing over 7 000 liters of milk/ha yearly.

lands. The following table shows only slightly higher weight gains obtained from properly fertilized pastures on an irrigated level Vertisol than on an Ultisol with 35% slopes and with 1 600 mm/yr of rainfall (Vicente-Chandler *et al.*, 1964):

Grass	Gains in weight (kg/ha/yr) Level Vertisol	Steep Ultisol
Guinea	1 292	1 179
Napier	1 327	991
Pangola	1 063	1 004
Average	1 227	1 058

Properly managed pastures of tropical Kudzu and molasses grass on 50% slopes carried 2.5 head/ha throughout the year and produced about 500 kg of weight gain/ha/yr (Vincente-Chandler *et al.*, 1964). However, in densely populated Puerto Rico the land must be used more intensively.

Various grazing experiments with Napier, Pangola and Star grass pastures on steep Ultisols, summarized in the following table, showed that they responded strongly to 2,150 kg of 15-5-10 fertilizer/ha/yr (Vincente-Chandler *et al.*, 1974):

15-5-10 fertilizer (kg/ha/yr)	Gains in live weight (kg/ha/yr)	Carrying capacity (220 kg steers/ha)
800	550	2.9
2 150	970	5.3
3 500	1 240	6.4

The following table summarizes the results of several grazing experiments on steep Ultisols fertilized with 2 200 kg/ha/yr of 15-5-10 and shows that yields were highest with Guinea and Star grass

pastures with the young cattle gaining about .6 kg/head/day (Vincente-Chandler *et al.*, 1974):

Grass	Gains in weight (kg/ha/yr)	Carrying capacity (220 kg steers/ha)
Star	1 427	7.3
Guinea	1 319	6.5
Pangola	1 124	6.0
Napier	1 110	5.8
Congo	946	5.4
Para	781	4.5
Molasses	644	3.5

Average production of nine Holstein cows receiving no concentrate feed and grazing 4 ha of steep, well-fertilized grass pastures were 930, 1 680, 1 770, 1 840, and 2 190 kg/cow over five successive lactations, respectively (Caro and Vicente-Chandler, 1974). In a commercial dairy, 150 cows grazing 65 ha of well-managed, steep, tropical grass pastures and receiving no concentrate feed, produced an average of 3 400 liters of milk/cow/lactation with a calving interval of 13 months.

Average composition of the forage ingested by cattle grazing well-managed pastures of various tropical grasses studied over a one-year period showed their quality was as good as that of the best temperate region grasses, averaging 18.5% crude protein, 5.4% lignin, 1.5% silica, 0.2% P, and 0.47% Ca and having a 55–66% *in vivo* dry matter digestibility (Vicente-Chandler *et al.*, 1974).

Thus, well-managed grass pastures on steep Ultisols can produce over 1 000 kg/ha of gain in weight or 7 000 l of milk/ha/yr with cattle receiving no concentrate feed.

INTENSIVE MANAGEMENT OF PROTECTIVE CROPS

Tall growing perennial crops such as coffee, plantains, bananas, citrus, breadfruit, and papayas can be grown on steep Ultisols with proper conservation. Minimum tillage combined with the dense foliage and thick mat of roots of these crops when they are closely spaced and intensively managed, protects the soil against erosion. Contour grass strips, diversion ditches, or a cover crop can offer additional protection where needed.

Coffee

Coffee, bananas, citrus and shade trees are often intercropped providing cash crops, fresh fruits, green bananas (as a vegetable) and charcoal, with few inputs, low costs, and good conservation but with low yields. The leguminous shade trees provide some N to the system and by limiting yields make the coffee trees more stress tolerant. The banana, shade and coffee trees combined maintain a high humidity which favors entomogenous fungi which help to control citrus scale insects. Furthermore, the shade trees decreased leafspot damage by half and doubled yields of unsprayed bananas (Vicente-Chandler *et al.*, 1966). Although increasing yields of this farming system by better management and small inputs of fertilizer and pesticides may be desirable in some countries, the high yields required in Puerto Rico can only be obtained by intensive management of the crops grown separately.

Coffee grown in full sunlight produced higher yields than under shade trees at three typical locations in Puerto Rico as shown in the following table (Abruña *et al.*, 1965):

Variety	Yields of marketable coffee (kg/ha) Full sun	Shaded
Mundo Nuevo	2 570	1 540
P.R. 401	2 310	1 280
Caturra	1 710	1 010
Red Bourbon	1 850	1 480
Average	2 110	1 328

Control of the coffee leaf miner by an annual application of Dysiston to the soil increased yields of intensively managed coffee from 1 460 to 2 210 kg/ha/yr (Vicente-Chandler, 1969).

The following table shows that with all other nutrients applied in abundance, 150 to 300 kg/ha of N or K are needed to maintain coffee yields at about 2 000 kg/ha on a steep Ultisol (Vicente-Chandler *et al.*, 1969):

N or K applied (kg/ha)	Yields of marketable coffee (kg/ha) With N	With K
0	1 260	1 320
150	2 140	2 030
300	2 480	2 480

A system was also developed which drastically reduces costs and coffee bean losses in harvesting (Vicente-Chandler *et al.*, 1975). Instead of going over the plantations several times picking the ripe berries by hand, the ground under the coffee trees is covered with plastic nets. These are collected about every 6 weeks and simple equipment used to remove twigs and leaves and to wash the coffee beans.

This system of intensive management practices including close planting in full sunlight, pest control, heavy fertilization, liming and harvesting with nets results in yields of over 2 000 kg/ha of marketable coffee in commercial plantations and high profits (Vicente-Chandler *et al.*, 1969; 1975).

Also, the high cost of establishing new coffee plantations can be offset by intercropping first with plantains and later with taniers or cocoyams (Vicente-Chandler *et al.*, 1975). Plantains are planted in rows with coffee planted later between them. After two plantains crops, they are removed and replaced with a row of taniers for weed control and to provide additional income. After three to four years, the

Figure 3. Intensively managed coffee plantation using the net system of harvesting which drastically reduces costs and loss of berries compared to hand picking. The coffee trees are allowed free growth and the lower branches are removed to facilitate working under the trees. Plastic nets are laid out between rows and cover all the ground like a carpet. Berries, leaves and twigs fall naturally on the nets and are collected about every six weeks. Simple equipment is used to remove leaves and twigs and wash the beans.

coffee is producing heavily so no further intercropping is needed.

Plantains and Bananas

Plantains have many advantages as a major source of food for millions in the humid tropics. They can be planted throughout the year to provide a steady food supply and can produce several crops without replanting. They can tolerate several months of drought and yet produce reasonable yields while other crops would fail completely. Plantains are immune to Panama disease and resistant to leafspot, both major pests of bananas. Plantain major pests are nematodes and grubs which can be controlled with systemic pesticides that can be easily applied by hand. Also, plantains can be cooked in many forms e.g. boiled as a vegetable, fried as chips, dried and ground into flour, boiled or fried ripe as a dessert, etc.

Plantains can be grown with good soil protection even on steep slopes. If weeds are controlled with herbicides, they need no land preparation and they can be strip cropped with grasses without appreciably affecting yields, as shown by the following table (Vicente-Chandler and Figarella, 1962):

	Plantain yields (kg/ha)
Sod planting and strip cultivation	22 100
Complete land preparation and clean cultivation	23 760

Figure 4. Intensively managed plantains growing close together in 6-row hedges with a contour strip of grass between for erosion control. Three crops of plantains are produced without replanting, yielding 45 tons/ha/yr.

The following table shows the response of plantains, growing on an Ultisol, to N, P, K and Mg when all other nutrients were applied in abundance (Caro *et al.*, 1964):

Nutrient	Plantain yields (kg/ha)
All	20 700
O N	12 320
O P	8 400
O K	13 660
O Mg	10 530

The following table shows that the application of nematocides sharply increased plantain yields over 2 successive crops (Roman *et al.*, 1975):

Nematocide	Plantain yields (kg/ha) 1st year	2nd year
Tensulfathione 15G—33 g/plant/6 month	28 700	22 260
Prophote 10G—56 g/plant/6 month	23 120	22 600
Carboturan 10G—56 g/plant/6 month	28 240	22 240
None	21 600	0

The following table shows that plantain yields on a steep Ultisol increased as plant populations were increased up to 3,530 plants/ha (Irizarry *et al.*, 1975):

Plant population (plants/ha)	Plantain yields (kg/ha)
2 120	26 900
2 650	37 860
2 930	38 100
3 530	44 570
4 250	45 920

Plantain cultivars, which produce bunches weighing 20 kg with 60 fruit/bunch, have been selected in Puerto Rico.

By growing high yielding cultivars of plantains close together, plus proper pest control and fertilization, plantains can produce 45 000 kg/ha of fruit, containing 27 000 kg of edible pulp or 10 000 kg of dry carbohydrates with the caloric equivalent of 10 MT corn.

Bananas planted close together, with no land preparation, proper weed and insect control, adequate fertilization, and with shade trees to control leafspot, can produce 30 MT/ha of bananas on steep Ultisols with good soil conservation for many years without replanting.

Other Protective Crops

Oranges, breadfruits, papayas, and pigeon peas are other tall-growing crops which can be grown on steep Ultisols with proper soil conservation and high yields.

Over 100 000 oranges/ha are obtained on steep Ultisols in Puerto Rico by using high-yielding varieties grafted on to disease resistant stock with proper pest and weed control, and adequate fertilization and liming. Oranges can be intercropped with plantains or bananas to provide income during the first years, with erosion controlled by contour grass strips complemented by diversion ditches or a cover crop, if needed.

Breadfruits, which can be boiled as a vegetable, are an important food crop for home use in the humid tropics and do well on steep Ultisols with grass grown under the trees to control erosion. Breadfruits are difficult to pick from the tall growing trees but this problem may be solved by grafting or pruning. Methods for storing the fruit also must be developed since it remains edible for only a few days after picking.

A system of intensive management practices for papayas, consisting of growing high yielding varieties close together with heavy fertilization, proper liming, periodic insecticide spraying and erosion control by contour grass strips and diversion ditches resulted in yields of over 100 MT/ha of papaya in a commercial operation on a steep Ultisol (Llorens and Vicente-Chandler, 1976).

Pigeon peas are an excellent protein source, the main dietary deficiency in the humid tropics. The rather tall bushes can be grown on steep Ultisols

with no land preparation and with contour grass strips to further help control erosion. Pigeon peas are drought tolerant, have few important pests, and can forage effectively for nutrients in Ultisols and Oxisols, as evidenced by their lack of response to fertilization on these soils. With proper management, they have yielded 2 500 kg/ha on Oxisols in Puerto Rico.

NON-PROTECTIVE CROPS

In the tropics, taniers, yams, cassava and soybeans are important food crops which are not in themselves soil protective or well suited to soil conserving management systems. However, limited plantings of these crops can be grown on hill lands alternately with contour grass strips or on bench terraces to provide variety in the diet and to reduce risks by diversifying farm operations.

Taniers or cocoyam (*Xanthosoma* sp.) tubers are used for human consumption throughout the humid tropics and the corms can also be fed to pigs. Taniers are rather unique in that they have few major pests, probably because oxalic acid in the skin of tubers and corms protects them from insects and nematodes. Taniers have low fertility requirements but can be set back by dry periods or affected by root rot if rainfall is excessive.

Cultivars of the Morada variety yielding 4 kg/plant of commercial tubers and 4 kg/plant of corms two years after planting, have been selected in Puerto Rico. At 20 000 plants/ha over a two-year period yields could be as high as 80 000 kg/ha of tubers, containing 60 000 kg of edible pulp (similar in nutritive value to potatoes) and 80 000 kg/ha of corms.

Yams are another important root crop of the humid tropics. The following table shows the cumulative effect of various cultural practices on yields of the Guinea Blanco variety of yam growing on a steep Ultisol and the high yield potential of this crop if properly managed (Caro *et al.*, 1968):

Treatment	Yields (kg/ha)
1. 11 000 plants/ha	13 300
2. 18 000 plants/ha	25 200
3. 18 000 plants/ha + staking	33 900
4. 18 000 plants/ha + staking + planting in raised beds	43 900

Cassava, which can be eaten as a vegetable or made into flour, is one of the major food crops of the humid tropics. It has low fertility requirements, few major pests, and the tubers can be left in the ground for extended periods without spoiling, but after harvesting have poor storage qualities.

Soybeans are high in protein and oil and can yield heavily during most of the year, as shown by the following data with the Hardee variety on an Ultisol (Silva *et al.*, 1972):

Month of planting	Soybean yields (kg/ha)
January	1 407
March	3 690
May	4 420
July	3 480
September	3 150
November	2 140

Two crops can be obtained yearly with total yields of about 7 000 kg/ha/yr of soybeans, containing 2 800 kg of good quality dry protein (enough to provide the protein requirements of 100 persons for one year) and 1 400 kg/ha of oil.

INTENSIVE HILL LAND FARMING SYSTEMS

The crops and management practices described in this paper are well suited to family size farms. The equipment and techniques are simple and can be used on small farms; labor requirements can be distributed rather uniformly throughout the year (so that little outside help is needed); the high income per unit of land permits a reasonable standard of living; the diversity of crops reduces risks and provides a varied, balanced family diet, and conservation measures ensure a permanent agriculture.

The various crops can be combined into a variety of highly productive farming systems. For example, a well balanced, family farm operation on 10 ha of steep Ultisols could consist of two ha of intensively managed coffee, as a cash crop; one ha oranges as a back-up cash crop during the off years for coffee; one ha plantains for sale in the local market or for home use; 0.5 ha taniers, yams, and cassava, together with a few breadfruit and other fruit trees to provide a varied diet; 0.5 ha pigeon peas and some soybeans to provide the necessary proteins, and 5.0 ha of intensively managed pastures to provide milk for the family, draft animals if needed, and beef for sale or home use. Such a diverse, intensive farming system could provide a reasonably secure cash source and an abundant well balanced diet with minimum risks.

Neglecting even one practice in an intensive farming system can be disastrous, while applying all the practices in a systems approach can result in a multiplier effect on yields and profits. With coffee, for example, using improved varieties can increase yields 20%, proper pest control can increase yields 40%, growing coffee in full sunlight rather than under shade trees can increase yields 40%, proper liming and fertilization can double yields, closer plantings can increase yields 50%, and harvesting with plastic nets can decrease berry loss 30%. When all those practices are combined, however, yields

can be increased tenfold over those obtained with the traditional system described previously.

To convert hill lands in the humid tropics to intensive farming systems, a massive program will usually be needed including: (1) demonstration of the farming systems on private farms; (2) effective extension and training programs; (3) adequate, technically supervised credit; (4) availability of essential inputs and services; (5) an assured market at reasonable prices; (6) a minimum of roads and other facilities; and (7) possibly even direct incentive payments for carrying out the more complex, costly practices.

Given the proper incentives, even uneducated farmers will accept and practice new techniques, not involving use of complex equipment. In the 1920's, a private company came to Puerto Rico with a system of practices for producing high yields of good quality tobacco, the necessary supervised credit, and a guaranteed market at reasonable prices. In a few years, the small farmers attained the skills required in the complex operation of growing and curing tobacco and attained yields and quality similar to those of farmers on the U.S. mainland.

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DISCUSSION

deVries (Pennsylvania, USA). What type of people are you using to implement these techniques? I was in Puerto Rico in 1969 for a short time, advising then Governor Ferre on rural development, and there were two possibilities as I saw it at that time and I'd like your judgment: One would be to have Puerto Ricans coming back from the mainland; very often there's some capital and know-how. The other would be the people that had stayed all their life in Puerto Rico and maybe would be susceptible to a change in their lifestyle by using these intensive agricultural methods. Which of the two or both, do you think would be acceptable in your program?

Vicente-Chandler. Puerto Rico has very few farmers in the sense that there are in the states. The island's agriculture developed in two ways—the plantation type with the traditional large coffee or sugar plantation and the weekend farmers who would rely on overseers to do the work. Obviously, this man cannot be converted to an intensive type of agriculture. On

the other extreme was the tobacco and food crop subsistence farmer—he had two or three ha from which he barely scratched a living. This man also is not susceptible to being converted to this type of agriculture. Furthermore, the sons of the large landowners are doctors, lawyers, businessmen, and so on. They do not see a future in agriculture. Puerto Rico industrialized very quickly and here was a place to make money. Obviously, the sons of the small farmer, seeing what happened to their parents, either went to New York or into manufacturing jobs. Puerto Rico has had a deteriorating agriculture over the last 30 or 40 years and there is a tremendous challenge in creating a new type of agriculture with new techniques and new farmers. This will require a tremendous effort on the part of the government. More than a question of money, it is a question of directing what Puerto Rico's agriculture should be in the future. Over the last 25–30 years the government has assigned funds to agriculture mostly to keep farmers surviving on the land on a government dole. This doesn't draw the type of farmer that it takes to create this type of agriculture. It is going to take a dramatically different outlook to Puerto Rico's agriculture than we have had during the last 30 years.

deVries. In many cases you say that these people are not easily persuaded to use these intensive methods. What are the type of people you are aiming at?

Vicente-Chandler The key to the whole thing is new technology. There are very few places in the world where you can make more money out of agriculture than Puerto Rico. For example, with the system of intensive coffee production, harvested with nets, net profit is $2,000/ha a year. In the case of plantains it's well over $2,000/ha. We import about 75% of all our food, and prices are very high. Your competition is back in the last century. So by doing things scientifically, you're so far ahead of the competition that people with entrepreneural interest have come into agriculture. The recession showed us that our industrial base and tourism base could be shaky and that the land was something that could provide a decent livelihood, not only in the hill lands, which I think are best suited for family type farms, but also on the low lands which are suited to modern mechanized production. For example, on the level lands we have shown that you can produce an average of 6 tons of rice per ha twice a year, each one with costs similar to those in the United States. Also, by planting the year around you can make much more efficient use of machinery. There is a tremendous potential there, but it is very difficult to change the attitudes of people.

Brown (West Virginia, USA). Do you find that by inter-cropping Guinea grass (*Panicum maximum*) and a legume you can reduce the amount of fertilizer that you use? How much would you use?

Vicente-Chandler. This is a very good question and I think it's open to debate. In Puerto Rico we have gone the route of alfalfa and different temperate zone legumes many times and failed. We have also tried tropical Kudzu and grass with some success. It's capable of maintaining about two head/ha throughout the year but its very difficult to maintain the right species balance.

After 8 or 10 years Kudzu goes out and you are faced with reestablishing it, which is expensive on hill lands. Also, due to the high value of the land, we have gone mostly to heavy fertilization and high carrying capacity. Now, this mixture that you mentioned is used to a slight extent on the south coast which is wet-dry tropics (about 80 cm poorly distributed) and Guinea grass does well and the legume can help keep up the quality of the forage ingested by the livestock during the long 5- or 7-month dry season.

S. B. Nepali (Nepal). You have pretty well described an intensive pattern on a small scale and you said that one ha of land contains eight people, similar to that in Nepal. I'm interested in whether this intensification, this technology, will help farmers in our two countries, but I was wondering: Is it the countries in general with land holding differences? Are there any people with small holdings and, if so, who are they?

Vicente-Chandler. The coastal lands are generally in rather large holdings and the eastern part of the Island in very small holdings. The coffee region, which used to be in large holdings, is being split up into smaller holdings because the coffee farmers are in very poor financial condition and are selling their land. The government is buying it and dividing it into family size farms. One good question is: "You have an extension service and you have these techniques, why isn't it moving much more quickly to the farms?" I think that one of the problems is that our extension service has been copied directly from that in the states. You do not get to a poorly trained farmer by leaflets, TV programs, or radio. You have to take him and show him what can be done on his neighbor's farm. I think this has been an error in Puerto Rico and a lot of tropical countries which I have visited. The complete package has to be proved on private farms and then extension must take groups of farmers to these private farms and, if possible, let the farmer explain how he does it and how much money he makes. This way you can progress almost geometrically, but preaching to them is not going to do it. I think this has been one of our failures.

10A.
The Appalachian Mountains

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The Appalachian Mountains are vast and many-featured, with a geological history of hundreds of millions of years. It is impossible to do more than to present a superficial view in an address no more than an hour in length. I have chosen to highlight the botanical features alone and to do it through the eyes of the original observers.

Somewhat as to a new Garden of Eden the European explorers in the eighteenth century came to America, to the awesome Appalachians. Behind them were the long-cultivated and much-abused lands and societies of the Old World. Before them were the rich soil, the clear streams, the virgin lands of the New World. Unbroken forests marched over the mountains, filled all the valleys; everywhere was the murmur of leaves, the trickling or rushing of sparkling water, the melody of strange birds in the trees. And always new plants and new animals.

John Bartram (1699–1777) was the first native-born naturalist of the New World, spending his early days on a farm near Philadelphia. He tells how he became interested in botany:

"One day I was very busy holding my plow (for thee seest that I am but a simple plowman) and being weary I ran under the shade of a tree to repose myself. I cast my eyes on a daisy, I plucked it mechanically and viewed it with more curiosity than common country farmers are wont to do; and observing therein many distinct parts, some perpendicular, some horizontal. *What a shame, said my mind, that thee shouldst have employed so many years in tilling the earth and destroying so many flowers and plants without being acquainted with their structures and uses!*"

With this beginning he botanized all over his farm, "ventured into Maryland" and beyond, increasing his knowledge as he lengthened his journeys, "crossing rivers, climbing mountains, and precipices—often following the paths made by the beasts of the forest." He mentions the "Blue Mountains" and meeting John Clayton, for whom Jan Gronovius named the lovely Spring Beauty (*Claytonia virginica*) and saw the incredible Natural Bridge. Peter Kalm, a student of Linnaeus, came from Sweden to study American plants, and Bartram helped him; the state flower of Pennsylvania (*Kalmia latifolia*) reminds us of that visit. Kalm tells how Bartram found the broadleaf plantain in so many places, and asked the Indians about it, and they told him that wherever a European walked, the plant grew up in his footsteps and for that reason they named it "the white man's foot."

The charming and delicate Apple Moss (*Bartramia*) is a memorial to John Bartram.

William Bartram (1739–1823) was a son of John, growing up with many advantages lacking to his father. His travels took him even farther away from Philadelphia and he became the first naturalist to explore the fantastic southern Appalachians, "all alone in a wild Indian country, a thousand miles from my native land." Entering the wilderness, he says:

"My next flight was up a very high peak, . . . where I rested; and turning about found that I was now in a very elevated situation, from whence I enjoyed a view inexpressibly magnificent and comprehensive. The mountainous wilderness through which I had lately traversed . . . appearing regularly undulated as the great ocean after a tempest . . ."

William and his father traveled south to Georgia; there, along the Altamaha River, they discovered, on October 1, 1765, a beautiful shrub unknown to science. Humphrey Marshall, William's second cousin, named it Franklinia for their neighbor and friend, Benjamin Franklin. It was planted in Bartram's garden in Philadelphia, where it has been perpetuated. But no one has seen it in the wild since 1803.

André (1746–1802) and François (1770–1855) Michaux: No portrait of André Michaux has survived, if, indeed, one was ever made; but his distinguished son was portrayed many times. Born near Versailles, France, André married at 23 and was ready to settle into the quiet life of a farmer. But his happy state ended in less than a year when his wife died in giving birth to François. Grief-stricken, the father changed his entire life style, becoming a wanderer and a student of the plant sciences.

On October 1, 1785, André arrived in New York, with the fifteen-year-old François. Two years later they moved to Charleston, South Carolina, which became their adopted home. Donald Culrosso Peattie, in "Green Laurels," describes André's captivation by his new environment:

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"A Frenchman from gentle Satory, where there are no diamond-back rattlers, *parbleu*, or animals who carry their babies in pockets of their fur coats, he saw all things American as curious and fascinating—and are they not?"

On December 8, 1788, a cool, rainy day, André relates, their travels took them to the headwaters of the Kiwi River in North Carolina. "We stopped there to camp and I ran off to make some observations. I gathered a new low woody plant with saw-toothed leaves creeping on the mountain at a short distance from the river."

Don't forget this "low woody plant with saw-toothed leaves!"

In the summer of 1793, André travelled beyond the Appalachians and down "la Belle Riviere," the beautiful Ohio. It was perhaps on this trip that he first saw the plant to which he gave a Latin name and which has been known until recently only as *Synandra hispidula*. A few years ago I suggested for it the English name Guyandotte Beauty, calling attention to its beauty (and it is beautiful) and also to its limited range, restricted in general to the old home of the Wyandotte (or Guyandotte) Indians, in the lower Ohio Valley.

On August 30, 1794, André stood on the summit of Grandfather Mountain, which he thought to be the highest peak in all the Appalachians, where his party chanted the Marseillaise and shouted "Vive l'Amerique et la Republique Francaise." "To those who have seen the Alps," Peattie says, "no Appalachians are likely, as mountains, to stir the heart. They are rather, a forest upon a high-rolling floor, and on all the continent, in all the world, I believe, is no such hardwood or deciduous forest as this." Doubtless André Michaux agreed.

John Fraser (1750–1811) was born in Scotland and made seven trips to America to study its lovely plants. Several of them bear his name, including the gentian, *Frasera*, and the Fraser Magnolia (*Magnolia fraseri*).

Another plant named for him has had an interesting history. It was first found about 1800 by a German explorer, Matthias Kinn, a man of gigantic stature and imposing appearance, who travelled extensively through the Appalachians, often without knowing where he was, because maps were few and misleading. He labeled his collection of the plant *Coronopitus tripitus* and added the notation "Deigher Walli in der Wilternus." Fraser found the same species "upon the banks of the Catawba River, in the neighborhood of Morgan-Town, North Carolina" and it was named for him *Carex fraseri*. Much later it was speculated that Kinn's "Deigher Walli" referred to Tygart Valley, West Virginia, although the species was not re-discovered there until 1963, by John Findley and Arden Swecker.

Constantine Samuel Rafinesque (1783–1840) was perhaps the most eccentric of the early botanists who explored the Appalachians. He was born in Constantinople, of a French father and a German mother, and came to America as a teenager. On a return trip to Europe he acquired books, manuscripts, drawings, plant collections, a wife. After ten years he set sail again for the New World; at the end of a long ocean voyage the ship was wrecked off the coast of Connecticut, and his books and papers were lost. Shortly after this he lost his wife, too, she having deserted him for a Sicilian actor.

In 1818 he crossed the mountains to the Ohio and descended the river to Hendersonville, Kentucky, where he "spent some days with Mr. Audubon, Ornithologist, who showed me his fine collection of colored drawings, which he has since published in England."

Later he obtained a professorship at Transylvania University, in Lexington, Kentucky, the first college west of the Appalachians. Here he became a "pedestrian botanist" and explored extensively the western slopes of the mountains, including the Cumberland Gap. "Horses were offered to me; but I never liked riding them, and dismounting for every flower; horses do not suit botanists."

But he did not get along well with Mr. Holley, president of the University. Returning to Lexington following the summer vacation in 1825 he found that the president had "broken open my rooms, given one to the students, and thrown all my effects, books and collections in a heap in the other. He had also deprived me of my situation as Librarian and my board in the college. I took lodgings in town and carried there all my effects; thus leaving the College with curses on it and Holley; who were both reached by them soon after, since he died next year at sea of the yellow fever . . . and the College has been burnt in 1828 with all its contents."

The "Curse of Rafinesque" is still pronounced on the Transylvania campus as part of a mock ritual!

But, eccentric or not, Rafinesque has left his imprint on Appalachian botany and his name is memorialized in those of numerous native plants, including the lovely wild pansy, *Viola rafinesquii*.

Thomas Nuttall (1786–1859), born in England, became the most travelled of any American botanist until his day; he finally crossed the continent all the way to the Pacific.

On one of his trips he came to Harpers Ferry to view the confluence of the Shenandoah and Potomac rivers, and pictured with enthusiasm "the stupendous scene so elegantly described by the ex-president Jefferson . . . where the rivers . . . uniting, appear to burst their way thro' the Blue Ridge, . . . a landscape of horrible grandeur and wild magnificence, of mingled rocks, roaring rivers, and gloomy forests."

At Asheville, North Carolina, he said, "I am on

the ground which poor Lyons has once travelled with so much assiduity—but, alas, his labors are at an end." Later he named a genus of the heath family *Lyonia* commemorating "the name of the late Mr. John Lyons, an indefatigable collector of North American plants, who fell a victim to a dangerous epidemic amidst those savage and romantic mountains which had so often been the theatre of his labors."

Charles Wilkins Short (1794-1863) was a physician and botanist of Lexington, Kentucky, one of the first scholars to be born in the wild country just to the west of the Appalachians. He made botanizing trips with Rafinesque and was visited by Nuttall in 1816; the two developed a warm friendship and they exchanged letters for more than forty years.

Asa Gray, a young botanist from New York State visited France in 1839 and studied the herbarium of André Michaux, preserved in the Paris Museum. Here he came across, among *plantae ignotae*, the specimen of the "low woody plant with saw-toothed leaves" which Michaux had first seen on that rainy day in December, 1788. Dr. Gray reported:

"We have the fruit, with the persistent calyx and style but no flowers." He guessed that it was allied to *Galax*. "I claim the right of a discoverer to affix the name. So I say, as this is a good North American genus and comes from near Kentucky, it shall be christened *Shortia*, to which we will stand as godfathers. So *Shortia galacifolia*, Torr. and Gr., it shall be. I beg you to inform Dr. Short, and to say that we will lay upon him no greater penalty than this necessary thing—that he make a pilgrimage to the mountains of Carolina this coming summer and procure the flowers."

But Dr. Short never made the pilgrimage and never saw the plant that was his namesake.

Asa Gray (1810-1888) is the best known of all American botanists. He was born in Oneida County, New York, and eventually became a professor at Harvard University, where he assembled the library, the herbarium and the students and wrote the books that made his name famous.

In the summer of 1841 he made a trip to the southern Appalachians, searching for, among other things, the plant he had named *Shortia*. But in this search he was unsuccessful.

Again, in the summer of 1843, with William Starling Sullivant, a bryologist, he traveled through the mountains of western Virginia down to North Carolina and Tennessee, the happy hunting ground of so many distinguished botanists. Years later Gray recalled "the varied incidents of the arduous but delightful journey, . . . the laborious mountain ascents, the night bivouacs, the healthful woodland life and primitive fare, and the many amusing adventures" of the tour which took them "along the principal length of the Alleghany Mountains, through much of their most picturesque scenery, and through regions which abound with the choicest botanical treasures which the country affords."

In North Carolina they "got fine near view of Black Mountain; passed the night not far from its base (twelve miles from Asheville). Should have ascended, but could not do it so as to get back Saturday night to any place to stay."

"Tuesday, got *Buckleya* in fruit . . . Buckley is often inquired after here, and seems to have been quite a favorite. He might have enlivened his journal had he informed us therein that he visited both Black and Bald Mountains with a merry company of ladies, and camped out on the summit! But the sly fellow kept all this to himself."

Black Mountain, which Dr. Gray thought he "should have ascended," but didn't, was already being studied by another botanist, Elisha Mitchell, of Chapel Hill, who would presently give his life in its exploration (June 27, 1857) and, as a memorial to him, have the highest point of land east of the Rockies named in his honor.

The 1843 trip of Dr. Gray, although rewarding in many ways, was a disappointment in that he failed again to find *Shortia*.

And so the years went by, filled with a multitude of great things for Dr. Gray. But when he thought of *Shortia*: "I grew sorrowful at having named for Dr. Short a plant that nobody could find. So conspicuous for its absence had this variety become, that friends of ours, botanizing in the mountains two years ago, were accosted with the question—'Found *Shortia* yet?'"

At last, in May, 1877, fourteen years after the death of Dr. Short, a seventeen-year-old boy, George McQueen Hyams, finally found *Shortia*, on the banks of the Catawba River, near Marion, North Carolina.

Hyams sent a specimen to Gray and in the spring of 1879 Dr. Gray, with three friends, made yet another trip to the Southern Appalachians. On the June 3 they were "on Roan Mountain, . . . at an elevation of about 6,200 feet above the sea, enjoying glorious views of range after range of the Alleghany Mountains, and on the grassy plateau *Rhododendron catawbiense*, perhaps more of it than in all the rest of the world, just coming into blossom."

At last they reached the locality where Hyams had found the rare plant and Gray and his friends had the distinct pleasure of seeing *Shortia* growing in the wild. His search ended, Dr. Gray exclaimed: "Now let me sing my *nunc dimittis*."

Nathaniel Lord Britton (1859-1934), through an interesting combination of several apparently unrelated circumstances, was involved in an engrossing episode of Appalachian botanical history.

Kate Carpenter, wife of one of the first settlers in Greenbrier County, Virginia (now West Virginia),

took refuge from the Indians about 1750 on the mountain that still bears her name; later the invalid wife of another settler was restored to health after bathing in water from nearby white sulphur springs and drinking of the water; a tavern was built near the springs, and a row of cottages, the resort presently becoming a center of fashion, a favorite rendezvous of elegant plantation society of the Old South.

In 1873 the Chesapeake and Ohio Railroad was completed across Virginia and West Virginia, passing through White Sulphur Springs. Now that transportation was easier, the fashionable, with a sprinkling of the notable, began to visit the springs with greater frequency.

In 1891 the New York Botanical Garden was authorized by the state legislature, 400 acres were set aside in the Bronx, and Nathaniel Lord Britton was appointed as the first director of the Garden. Under his direction the dreams of the founders were realized and the institution became one of the greatest botanical gardens in the world.

Members of the staff of the new Garden, including Dr. Britton and his friend, Judge Addison Brown, made excursions into many regions of the North American continent. A favorite resort was White Sulphur Springs, where a vacation could be combined with botanical studies in the mountains. One might picture a botanist, after a good lunch at the "Old White," walking across the street and the C & O tracks, and climbing the slopes of Kates Mountain, where a sparse vegetation clothed the dry slopes.

Here, in July, 1892, John Kunkel Small discovered a new clover, which he later named *Trifolium virginicum*. On May 16, 1897, Dr. Britton found a new ragwort which he called *Senecio antennariifolius*. In May, 1898, Dr. Britton found a new phlox named by Small *Phlox brittonii*. Kenneth Kent Mackenzie, a New York lawyer and member of the Garden, on August 23, 1903, found a large-flowered evening primrose which he named *Oenothera argillicola* and six days later found another plant which would fit into no known genus; this he later named *Pseudotaenidia montana*.

The discovery of so many new and endemic species in such a small area, at a time when the Appalachian Mountains were becoming fairly well known botanically, presently led to the conclusion that the environmental factors must include some unusual features. The plants were all found growing on dry Devonian shales, and in 1911 Edward S. Steele coined the term "shale barren" to designate this peculiar type of plant habitat. The barrens, it was found, extend in a long, narrow strip from southwestern Virginia north along both sides of the Virginia-West Virginia border, across Maryland, just barely entering south-central Pennsylvania; the interesting plants named above (and numerous others) occur dotted throughout the entire area. It was only the combination of circumstances that had led to the discovery of so many of the endemics at White Sulphur Springs. Describing a shale barren, Steele says it is "One of the most fascinating spots in which it has been my fortune to botanize."

Dr. Britton was one of my advisers when I began my doctoral work at the New York Botanical Garden. In a way, then, it might be said that the story is brought down to the present, and that 1976 marks the bicentennial of the botanical exploration of the Southern Appalachians. There are no longer vast geographical areas to be explored, no longer many new species to be discovered. Our task for these days is an infinitely more difficult one—the proper management of what we have found.

11.

Breeding Grasses and Legumes for Hill Environments in Britain

E. L. Breese

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The agricultural potential of hills and uplands in Britain is discussed by Hughes (1976). Farm systems are based on sheep, complemented to varying degrees by weaner-calf or store cattle production. A higher output depends primarily on pasture improvement which will provide a higher plane of nutrition for increased stock densities.

In the first place, the capacity for improvement depends on the feasibility of critical management factors, specifically soil amelioration and stock control. But the response to such management inputs depends on the replacement of existing vegetation by higher yielding and better quality grasses and clovers.

The general advantages and disadvantages of different lowland and upland species are considered by Munro (1976). Perennial ryegrass (*Lolium perenne*), timothy (*Phleum pratense*) and white clover (*Trifolium repens*) are preeminent in many grazed situations, although red fescue (*Festuca rubra*) has many merits. A number of species have potential for conservation.

AGRONOMIC REQUIREMENTS AND BREEDING EMPHASIS

The factors which are important in breeding improved pasture plants for hill land production can be listed as (1) total dry matter production, but with emphasis placed on an extended growing season, (2) improved nutritive value of the dry matter with regard to digestible energy, protein and mineral content, and (3) persistency, including resistance to disease and tolerance of environmental stresses such as winter cold and, depending on the soil conditions, summer drought (Hughes and Munro, 1969; Newbould, 1973). These also are the general objectives in breeding herbage plants for lowland conditions (Breese, 1975; Breese and Davies, 1976), and at the Welsh Plant Breeding Station we have sought to conjoin breeding programs for upland and lowland conditions, with a consequent economy of breeding effort and resources.

Climatic stress factors, particularly low temperature and low light intensities, are more pronounced under upland conditions, and there is, consequently, a greater requirement for winter hardiness generally. Winter hardiness is, however, also a problem under intensive lowland farm systems in some years, particularly in northern Britain. Indeed, the greater and more consistently adverse winter conditions of the hill environments are being used by the Welsh Plant Breeding Station to screen winter hardy plants for the lowlands. Again, farming conditions and standards vary enormously in lowland regions so that we have looked for plants which will do well over a range of soil types and fertility levels.

Primarily, therefore, our approach has been to breed grasses and clovers which are widely adapted to upland and lowland conditions. This approach has the advantage that seed of such improved varieties would be cheaper and more readily available commercially than would seed of specially adapted varieties. Nevertheless, with a better characterization of the hill environment and a clearer understanding of the physiological potentials and limitations of the grass sward, the possibilities of more specifically adapted varieties are constantly under consideration.

Because of the low levels of available nitrogen in upland soils and the high cost of correcting this with fertilizer, great importance is attached to establishing pasture legumes and their associated nitrogen fixing rhizobia. A special consideration thus has to be given to grasses and legumes which co-habit successfully in the sward.

GENE SOURCES AND GENETIC RESOURCES

Indigenous Adaptations

Many present-day herbage varieties in the U.K. have been developed from indigenous material adapted to specific grassland systems. Well-grazed permanent pastures yielded prostrate, late flowering plants which were extremely persistent by virtue of a high capacity for tillering and hence vegetative reproduction. S. 23 perennial ryegrass originated from material of this type derived from fertile pastures where ryegrass predominate. This variety displays a remarkable versatility under grazing conditions over a wide range of soil fertilities and stock densities. It is still one of the foremost varieties for production and persistency under the heavy stocking and high nitrogen input of intensive lowland systems. It is also extremely persistent and productive under the relatively low fertilities of the hill lands, and indeed since 1940 it has been the main ingredient of mixtures for hill land reclamation in the U.K.

Lenient grazing coupled with cropping for hay evolved the erect, early-flowering and relatively low-tillering plant type which is the basis of our present conservation varieties. Although timothy, cocksfoot and the broad-leaved fescues predominated under these conditions on the more fertile soils, adaptations to both contrasting managements exist within the major grass species.

There is a similar pattern in legumes, but these species appear less able to adapt to extremes of management. Thus indigenous clover species tend to be exclusively adapted either to lenient grazing and conservation systems (e.g., red clover, *T. pratense*), or to more intensive and continuous grazing (e.g., white clover). Again, varieties of the indigenous, small-leaved, prostrate 'wild white clover' (e.g., S. 184) have proved extremely adaptable to both upland and lowland conditions involving controlled grazing and low nitrogen application.

The above emphasizes the overriding importance of cutting/grazing managements in the ecological adaptation and, hence, in the usage of many current grass and clover varieties. Provided that these managements are controlled, varieties developed from ecotypes can be exploited well beyond their regions of maximum adaptation in terms of soil and climatic conditions.

Plant Introduction

Indigenous ecotypes form only a small part of the genetic diversity offered by these widespread grass and clover species. A first step in meeting the increasing requirements of hill and lowland farm systems has been to build up genetic resources by

plant collections from various parts of Eurasia and North Africa. Material now held at the Welsh Plant Breeding Station is differentially adapted to grow under a wide variety of temperature, light, soil and management conditions, and includes variants which are tolerant of many environmental stress situations (Davies, *et al.*, 1973). The collection is of value in maintaining germ plasm of wild material and as a source of parents for breeding purposes.

For the most part, the collection has to be regarded as a source of raw material from which valuable genes and gene complexes have to be extracted and welded into agronomic varieties by complex breeding processes. Sometimes 'pure gold' is discovered when the populations can be developed into varieties by mass selection. Examples are diploid and tetraploid cocksfoot (*Dactylis glomerata*) from north-west Spain which have a tillering capacity previously unknown in the species and are able to maintain extremely dense swards under a range of cutting heights and frequencies. These plants have exceptional drought resistance and could be a valuable introduction on the drier soils of the hills (Munro, 1976).

The contrasting material in these collections has greatly facilitated studies into the physiological and biochemical processes which underlie adaptation and differentiation (Cooper, 1974). These studies have identified plant characteristics which are important in governing sward performance and in determining the nutritive value of the plant (Cooper and Breese, 1971; Jones, 1975). At the same time, cytogenetic studies reveal the scope for, and the means of, combining and recombining characteristics from different races and species (Thomas and Thomas, 1972).

This multi-discipline approach is providing a sound basis for the determinate development of agriculturally useful cultivars from the raw material.

BREEDING FOR WIDE ADAPTABILITY

Where differences between environments depend on a wide range of interacting climatic, soil and management factors, as in the range of hill/lowland conditions, there are massive problems in measuring the relative responses or sensitivities of plant material to the changing conditions. In the first instance, resort has to be made to empirical methods, and in this connection the 'joint regression technique' has proved useful (Finlay and Wilkinson, 1963; Eberthart and Russell, 1966; Breese, 1969). This technique involves growing contrasting genotypes (varieties, selections etc.) over a representative range of environments with suitable replication. An analysis of variance of data reveals any interaction between genotypes and the environments, and if these occur, the data can be further analysed by regressing individual genotype values on the environmental mean values of all genotypes under test. These mean values provide a biological index quantifying the environments from poor to good, and it has been found that genotype-environment interactions are frequently a reflection of differential linear responses to an improving environment. They can thus be measured as differences between regression coefficients.

The technique has wide application and has the advantage that data from a number of different experiments can be combined in comparing the performance of genotypes. Figure 1 depicts the average annual yield performance of three varieties of perennial ryegrass taken from a number of experiments conducted in different years and under different conditions which together provide a tremendous range of yielding conditions (Samuel, *et al.*, 1970). It will be clear that the technique gives a good indication of the environmental limits specifying the superiority of one variety over another. The linear nature of the responses also means that a wide range of relative performances can be predicted from trials restricted to a few contrasting environments.

Genetic studies have shown that *responses* of varieties and their mean performances over environments can be differentially adjusted by selection. The extent and type of adjustment depends on whether selection is carried out independently in a poor or good environment or simultaneously in both. It also depends on the initial correlation between response and *mean performance* (Jinks and

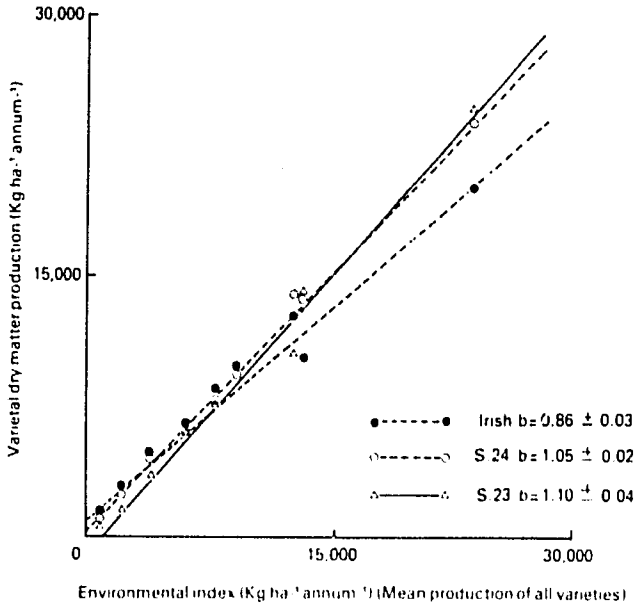

Figure 1. Analysis of genotype-environment interaction for dry matter production among varieties of perennial ryegrass (*Lolium perenne*); from Samuel *et al.*, (1970).

Connolly, 1973). Ideally, of course, we require a high mean and a high response.

The joint regression technique is used in the breeding programs to determine initial responses and mean performances of the breeding material and to decide on selection sites and methods. This empirical approach is forced on us where limiting environmental factors cannot be identified. It is also useful in monitoring the consequences of selecting for tolerance or resistance to particular features of the environment such as cold or drought.

BREEDING FOR TOLERANCE

Spring and Autumn Growth and Winter Hardiness

The requirement for an extended growth season in the hills, particularly early spring growth, has been strongly spelled out. Native species, generally, are adapted to a short growing season and often possess an extended dormancy system to escape the rigors of the winter climate (cf. *Molinia coerulea*). This applies to some extent to lowland species and varieties which are sufficiently hardy to withstand the hill climates. Thus hardy varieties of ryegrass tend to be slow in starting spring growth and in this respect are less useful than timothy or tall fescue.

It is generally agreed that for extended growth seasons we require grasses and legumes without dormancy or with reduced dormancy mechanisms. The accent is on material which can grow under low temperatures and low light intensities while retaining a tolerance of freezing conditions (Breese and Foster, 1971; Cooper and Breese 1971; Olerenshaw *et al.*, 1976). In a number of grasses and clovers, varieties and ecotypes differ greatly in their lower temperatures limits for growth (Cooper, 1963; Eagles and Østgård, 1971; Davies *et al.*, 1973). Thus ecotypes from the Mediterranean region can expand leaves quite actively at 5° C, whereas more northern varieties become semi-dormant at this temperature. However, this active growth at low temperatures is often associated with lack of frost tolerance and the breeder has to select for the most appropriate balance between these two characters to suit specific winter conditions.

Many factors affect the capacity of grass populations to survive winter conditions. All ryegrasses require a period of hardening at relatively low temperatures before achieving tolerance of freezing conditions. Experiments under controlled conditions show that the rate and extent of hardening is affected not only by the genotype, but also by light conditions and management prior to, and during, the hardening period (Lorenzetti *et al.*, 1971; Lawrence *et al.*, 1973; Breese and Foster, 1971). These results are summarized in Table 1. They show that lower light intensities and shorter photoperiods during hardening generally reduce the survival of the material. Survival is further reduced by autumn management factors which encourage growth, such as nitrate application and over-defoliation (Charles *et al.*, 1975). There are large differences between the varieties which are related to their origin, but the magnitude of these differences depends on the conditions of hardening.

The complexity of all these factors interacting together makes it difficult to breed for an acceptable degree of winter hardiness combined with utilizable late autumn and early spring growth. It calls for a fine genetic adjustment of the way the plant distributes its assimilates, either to storage in the leaf bases, etc., or to continued leaf expansion under specific growing conditions. Other factors also may be implicated such as resistance to pests and diseases, particularly the snow mold *Fusarium nivale* (Breese and Foster, 1971). At the Welsh Plant Breeding Station we use controlled environment chambers

TABLE 1. Effect of genetic and environmental factors on cold tolerance in *Lolium perenne* subjected to 14 days of hardening at 2° C and 3 days of freezing at −8° C

	% Tiller Survival			
(a) Light conditions during hardening (Lawrence *et al.*, 1973)	16th day 39 W/m² 62	8th day 78 W/m² 45	16th day 20 W/m² 41	8th day 39 W/m² 31
(b) Defoliation and applied N 10 days before hardening (Breese and Foster, 1971)	No nitrogen not cut 80	 cut 48	Nitrogen applied not cut 48	 cut 10
(c) Genetic: Population and origin (Lorenzetti *et al.*, 1971)	Veja (Lithuania) 81	Melle Pasture (Belgium) 68	S.321 (Scilly Isles) 44	Fano (C. Italy) 16

(a) and (b) = population means.
(b) and (c) = under 8th day and approx. 50 W/m.²

as a means of providing consistent screening media, but the results are verified in the field, particularly under rigorous upland conditions. The upland centers also provide survivors for further breeding work.

By these means, improvements in winter hardiness have been obtained by selection within varieties of Italian ryegrass which have a long growing season. Another approach is through the production of hybrids between northern and southern ecotypes. Thus Borrill (Rep. Welsh Pl. Breed. Stn. for 1966, pp. 51–53) has produced stable tetraploid cocksfoot hybrids between north European populations of *D. glomerata* and Mediterranean *D. lusitanica* which combine a useful measure of winter hardiness with an increased potential for out-of-season growth.

Low Nutrient Status and Specific Soil Conditions

That ryegrass genotypes can be selected for differential efficiencies in the use of nitrogen was shown by Vose and Breese (1964). Work by Valentine and Charles (1975) has shown that the versatility of S.23 perennial ryegrass referred to earlier is, undoubtedly, related to genetic heterogeneity with regard to performance at differing nitrogen levels, thus allowing natural selection of the most efficient genotypes at the different sites. A breeding program in ryegrass is now under way to increase, through selection, the amount of dry matter produced per unit of nitrogen supplied, and lines exist which have high expression for this character (Goodman, 1974). Variation also exists in the efficiency of phosphate uptake from the soil. Here the possibilities for improvement are not so well defined since better phosphate extraction from the soil depends largely on increased root growth and this could lead to decreased top growth and a consequent adverse effect on dry matter yield (Goodman, 1974 and personal communication).

Within perennial ryegrass there is a wealth of genetic variability in many physiological processes that may be manipulated to give more precise adaptation to varying climatic/soil conditions. Thus, at the Welsh Plant Breeding Station, Wilson (unpublished) has been able to achieve (a) a more efficient use of water in ryegrass and fescue by selecting for smaller or fewer stomata and for leaf ridging, and (b) a more effective use of assimilates in promoting growth of perennial ryegrass by selecting for a lower dark respiration rate. These studies have produced experimental varieties which are being tested under a range of soil and management conditions on hills and lowlands.

The extent to which these characteristics can be built into varieties as a means of extending general adaptability, as distinct from forming the basis of more precisely adapted varieties depends on their association with other characters, and whether this is due to unbreakable pleiotropic gene action or to breakable gene linkage. These are being determined by experiment.

Under hill land conditions we have to consider that naturally adapted red fescue populations have advantages over many lowland species in winter survival and early spring growth under a low nutrient status (Munro, 1976). However, they present problems in maintaining growth which is of a high nutritive value and acceptable to the animal through the mid summer period.

NUTRITIVE VALUE

Researches into the chemical and physical constitution of grasses and clovers have identified a number of characteristics which affect digestibility, voluntary intake and the metabolizable energy of herbage plants (Jones, 1975). Considerable genetic variation exists even within species, and selection for improvement is being carried out at the Welsh Plant Breeding Station (Cooper and Breese, 1971). The ryegrasses are generally of high digestibility, and here selection concentrates on factors affecting voluntary intake, particularly with regard to the amount and type of structural carbohydrates, the water soluble carbohydrates/protein balance and the available minerals. The low digestibility and acceptability of red fescue during the summer period has been associated with a high proportion of stem to leaf (Munro, 1976), and selection is being successfully practiced for later flowering varieties which have a concomitant reduction in this ratio and an improvement in digestibility. White clover maintains a high digestibility for most of the year since only the leaves and petioles are grazed or harvested. It is also high in protein and minerals and is thus a valuable addition to the diet of the ruminant animal on hills and lowlands.

ADAPTABILITY AND VERSATILITY

The ryegrass/fescue complex encompasses a vast range of types which are variously adapted to almost the full range of climatic, biotic and edaphic conditions that are likely to be encountered in temperate grasslands. Cytogenetic investigations have shown that a large section of this group is related to an extent which will allow hybridization and genetic exchange. In these studies our aim is to discover to what extent we can include in a single variety those attributes which hitherto could only be introduced into swards as mixtures of species or varieties, with all the attendant problems of competition and agronomic incompatibility.

Success has been achieved in producing genetically stable hybrids (allotetraploids) between Italian and perennial ryegrasses (Breese, *et al.*, 1975). The hybrids add a greater tillering capacity and persistency under cutting and grazing treatments to the otherwise excellent growth and nutritive charac-

teristics of Italian ryegrass. By judicious choice of parents, enhanced low temperature and water stress tolerances and resistence to disease have been achieved. The range of the new hybrids has recently been extended by the production of stable allotetraploids between the two ryegrass species and meadow fescue (*F. pratense*) some of which have shown a remarkable capacity to continue growth during the 1976 drought in the U.K. These hybrids provide a new dimension for producing early growth and conservation on the inbye hill areas.

THE ROLE OF THE LEGUME

The nitrogen-fixing capacity of legume/rhizobia associations has always been considered critical for the improvement of hill areas. White clover is still considered the most useful species for grazing and within this species the indigenous small leaved "wild white" group, of which S.184 is a variety, has proved the most persistent (Munro, 1976). Introductions from the Mediterranean countries have a longer season of growth, but these larger-leaved, longer-petioled populations are frost-susceptible and nonpersistent. Efforts are being made by hybridization and selection, as discussed earlier, to combine a potential for a longer growing season with acceptable levels of winter hardiness and persistence. Under upland and lowland conditions, however, there are considerable year-to-year variations in white clover production which require further elucidation and is the subject of agronomic and physiological study (Davies, 1974).

Of particular importance is the competitive/cooperative aspects of associated grass and white clover genotypes. The ability of white clover to compete with a companion grass under different cutting frequencies is related to its "stature" as measured by the size of the leaf and length of petiole and this principle has been used by Davies (1974) to select white clovers specifically adapted to different management systems. Rhodes (unpublished) at the Welsh Plant Breeding Station has shown that the aggressiveness of the associate grass can in turn be related to "stature" as measured by leaf length and erectness. Red clover has considerable promise as a conservation crop for the inbye areas. Selection here has focused on tolerance of colder conditions as well as resistence to clover rot (*Sclerotinia trifoliorum*). Variation in factors associated with bloat or infertility (oestrogen content) are also under study.

On certain hill soils, particularly on the more acid areas, white clover may fail to establish satisfactory N-fixing associations with the natural soil populations of *Rhizobium*. On some of these areas surveys have shown that *Rhizobium trifolii* is either absent or represented by strains which are ineffective with introduced material (Jones, 1966). Inoculation of white clover seed with effective strains of *Rhizobium* is thus considered to be essential, or at least a useful insurance, over a number of hill regions.

Although strains of *Rhizobium* may form reasonably effective nodules with a fairly wide range of genotypes, there is evidence that the efficiency of N fixation depends on a precise interaction between host and symbiont (Mytton, 1975a). The provision of *Rhizobium* strains which form efficient associations with clover adapted to hill land conditions forms part of a program designed to improve these associations in general through simultaneous selection of host and symbiont (Mytton, 1975b).

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DISCUSSION

Tim Taylor (Kentucky, USA). What scope is there for breeding *Rhizobium* as well as legumes for the hill lands and how successful have you been at this?

Breese. As I briefly mentioned in my paper, a good response in white clover growth has been obtained from inoculation with an appropriate *Rhizobium* strain, particularly on peaty soils. The response is less in the number of plants established than in the vigor of growth two months after establishment. The data that I showed indicate that this beneficial response is still evident 14 months after establishment, although by this time there is evidence of effective nodulation on the un-inoculated control plots—perhaps by cross contamination. We are still in the early stages of selecting *Rhizobium* strains for these environments but my colleague L. R. Mytton has isolated a strain from hill environments which has proved to be effective under these conditions in association with small-leaved white clover varieties such as S184.

Howard Kaerwer (Minnesota, USA). Could you tell us something about what ploidy level you're working with in the red fescues, and also whether you have any ideas about the heat tolerance and the growth characteristics of the fine fescues which are used for forage purposes?

Breese. My colleague J. M. Munro will be talking this afternoon about the potential of red fescue under our hill conditions and I would not wish to preempt what he has to say. Briefly, we have screened a wide range of red fescues but have worked chiefly with the 42-chromosome section. Our interest is in the fact that indigenous races of red fescue are adapted to survive the stresses of the hill land conditions, can grow early in the season, and are also capable of producing high yields of dry matter. The chief disadvantage is that they are less digestible and acceptable to animals than lowland grasses, particularly during the latter part of the season when continued growth produces stems rather than leaves. In this context, Munro and his colleagues are selecting later heading varieties which are less prone to produce stems and, concomitantly, have a higher digestibility and acceptability. I have no information directly on heat tolerance.

12.
Techniques for Hill Land Improvement Used in the United Kingdom

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About one-third (5.8 million ha) of the land in the United Kingdom (UK) being utilized for agriculture is defined as hill and upland. It occurs predominantly in Scotland, Wales, the Pennines and North of England, parts of Southwest England and the upland area of Northern Ireland. Over 70% of this area (4.1 million ha) is unimproved native grassland described as rough grazing. A striking feature of the rough grazing in the UK, which distinguishes it from much of the under-utilized native pastures in other parts of the world, is the marked "turf or matt" which develops to varying extents on all soil types. Its extreme form is seen in the blanket and hill peats.

The hills are used mainly for the breeding and rearing of domesticated ruminants, predominantly sheep and red deer, but not for dairy farming and the production of crops other than to feed the animals. Some farms with a proportion of enclosed readily cultivatable fields (inbye) or high quality upland pasture are used to fatten lambs and cattle.

The free range year-round set-stocked farming systems for sheep traditionally operated on hill land in the UK, although varying to some extent between the regions, have tended to result in marked underutilization of the available herbage (Eadie, 1976). In these systems the nutrition cycle of the hill ewe is poor. Recent work in Scotland (Eadie *et al.*, 1976b), in England (Thompson, 1973) and in Wales (Roberts, 1973) has shown that the key to improved production on hill sheep farms lies in pasture improvement to enhance ewe nutrition. The use of "two-pasture" systems with some improvement and more efficient utilization of both improved and unimproved vegetation results in higher stocking rates, more lambs per ewe, reduced ewe mortality, heavier lambs and more wool (Eadie, 1976). Thus, given favorable cost/price relationships, financial margins can be significantly enhanced.

This paper describes the chief features of some of the main categories of hill soil in the United Kingdom together with the vegetation they support, indicates how they are improved and emphasizes problems or discussion points which can arise.

HILL SOILS AND VEGETATION

Climatic and soil factors interact to form the existing vegetation and to limit its production. Climate is the dominant influence as it determines the soil-forming processes and affects the growth of the plants directly. The climate is cool, wet and windy and it deteriorates rapidly with altitude, particularly in the wetter western areas of the country. The soils are formed from rocks of Paleozoic or older age which can be sedimentary, igneous or metamorphic but which are all resistant to weathering, producing very acid, shallow and stony soils of poor structure, low in nutrients, especially calcium, phosphorus, trace elements and, most importantly, available nitrogen. Moreover, even the freely drained soils (Groups 3 and 5—see below) exhibit very strong fixation of added phosphorus due to the large surface area of amorphorus "allophanic" materials. The main types of hill soil in the UK have been described by Crompton (1958), formation processes were discussed by Floate (1968) and the resulting soil conditions and nutrient supplies by Reith (1973). Mean annual soil temperatures at 50 cm are usually $< 8^{\circ}$ C except in parts of Wales and near the western seaboard (Ragg and Clayden, 1973). For the present purpose, hill soils can be divided into five main groups (Ashton, 1970) although the first group is of little significance agriculturally.

1. Skeletal soils (Cryorthents): the screes and jumbles of hard rocks that occur on steep slopes, usually at higher altitudes.
2. Blanket and hill peats (Fibrists and Hemists): the depth of peat varies from 0.3 to 6.0 m or more. They are extremely acid (pH < 4.0) and although they contain large total amounts of N (10 000 kg/ha) and P (2 000 kg/ha) only small amounts (30 kg N and 40 kg P/ha) are available to plants.
3. Podzols (Orthods and Humods [Cryic, Fragic and Haplic great groups]): highly leached soils of poor structure extremely low in all nutrients, often with an organic (non-histic) or umbric epipedon, pH 4.3–4.6.
4. Gleys, peaty gleys and peaty gley podzols (Aquepts and Aquods [Cryic, Fragic, Placic and Haplic great groups]): soils with impeded drainage, generally with umbric or histic epipedons, pH 4.0–6.0. The nutrient status of the predominantly gleyed soils is higher than that of the podzols.
5. Brown earths (Ochrepts [Cryic, Fragic and Dystric great groups]): mineral soils of good structure

with moderate nutrient status but still acid by lowland standards, pH 4.6–6.0, % base saturation < 20%.

Only small areas of upland Britain have been surveyed in detail so that the overall distribution of these main soil types is not known precisely; moreover, some areas have extremely complex soil distribution patterns. However, in general terms the deeper Histosols and Aquods tend to occur in the western parts of the country with annual rainfall greater than about 1 500 mm. The potentially productive Ochrepts and mineral dominant Aquepts tend to occur at lower elevations throughout the hill areas although predominantly in central and eastern areas, and possibly extend to between 1–2 million ha.

The composition of the vegetation growing on these different soil types is determined mainly by soil drainage conditions, by soil pH, by the biotic pressure (grazing and/or burning) and by the climate. Detailed descriptions of hill vegetation types have been given by McVean and Ratcliffe (1962), King and Nicholson (1964) and King (1976) and the relationship of composition to the main soil, climatic and biotic factors in a recent bulletin (Ashton, 1970). A brief description of the principal hill vegetation types and their annual production of dry matter (Table 1) in relation to the main soil types shows that the most productive indigenous hill vegetation is a species-rich *Agrostis-Festuca* community found on the better drained brown earth soil of moderate pH. However, the level of production

TABLE 1. The main hill soil and vegetation types in the United Kingdom

Soil	pH	Short Title	Vegetation Variant	Main Species	Average Production (kg DM/ha/yr)
Brown earth	5.2–5.5	Acid grassland or Agrostis-Festuca	(a) Species rich	Agrostis tenuis Festuca rubra Trifolium repens Many herbs	3 500
	4.6–5.2		(b) Species poor	Festuca ovina Agrostis tenuis Agrostis canina Few herbs Sometimes Pteridium aquilinum	2 500
Gleys, peaty gley, peaty gley podzol	4.0–5.2	Grass—heath	(a) Purple moor	Molinia caerulea Festuca ovina Deschampsia flexuosa Vaccinium myrtillus	1 800
			(b) Moor mat	Nardus stricta Festuca ovina Deschampsia flexuosa	
Podzol/peaty podzol	3.8–4.5	Shrub—heath	(a) Dry	Calluna vulgaris Vaccinium myrtillus Erica cinerea	1 800
			(b) Wet	Calluna vulgaris Erica tetralix Tricophorum caespitosum Molinia caerulea Eriophorum sp.	1 500
Blanket peat	< 4.0	Bog	(a) Blanket	Calluna vulgaris Erica tetralix Trichophorum caespitosum Eriophorum sp. Sphagnum sp. Other mosses	
			(b) Cotton grass	Eriophorum sp. Calluna vulgaris Sphagnum sp.	1 300
			(c) Purple moor grass	Molinia caerulea Calluna vulgaris	

of this better type of hill sward is still poor by lowland standards (Table 4).

LACK OF AVAILABLE NITROGEN

As indicated in the preceding section, pasture growth is severely limited by lack of available nitrogen. The labile pool can be enlarged through the extra nutrient cycling which follows the additional utilization brought about by grazing control (Floate, 1971) and by the increased mineralization which follows the application of lime. However, these increases are not adequate to support high levels of production from the better acid grasslands or from sown lowland grasses. The annual application of nitrogen fertilizers to even small areas of improved pasture integrated with large areas of rough grazing in hill sheep systems cannot be justified on economic grounds (Eadie, 1973) and there is almost universal agreement that the required nitrogen can only be supplied by biological fixation with a legume (Munro, 1973; Newbould, 1974a), the one that best fits the climatic and soil conditions in the UK being *Trifolium repens* (white clover).

An additional reason for growing white clover is its high quality as a feed for ruminant animals (Rae *et al.*, 1964; Thomson and Raymond, 1970; Armstrong and Eadie, 1973). Not only is the herbage high in protein and minerals but, possibly because of its high digestibility, it enhances voluntary intake of a mixed sward and it appears that the utilization of the products of digestion from clover rich diets is better than from grass alone.

Thus the key to hill pasture improvement in the UK is to make soil conditions such that both the native and introduced white clover plants can grow and fix as much nitrogen as possible. Present data suggests that from 80–150 kg N/ha can be fixed annually by hill swards whose dry matter contains 20–30% white clover.

TECHNIQUES OF PASTURE IMPROVEMENT

A large number of different techniques are used in the UK and most have been described (NSCA, 1972; Frame, 1973). They range in cost, speed of response and persistence of improvement from the provision of a fence alone, enabling control of grazing, to the latter plus full cultivation and the application of fertilizers and seeds (Newbould, 1974b). The latter, if successful, brings about rapid change in herbage quality and production while the changes following the former are slower. The choice of a specific technique depends primarily on the existing plant community and the type of its underlying soil, on the needs of the grazing system and on the finance available. Physical features of the terrain, such as slope, degree of wetness, aspect and access are secondary determinants which influence the choice of site and technique. Figure 1 illustrates the vegetational changes that are theoretically possible to bring about pasture improvement, although not all have been demonstrated in practice on a field scale. The diagonal lines represent the cheaper but slower changes while the upward pointing arrows indicate that all existing communities can be changed at a cost to a white clover/grass sward although the responses in yield of dry matter to be expected differ across the spectrum of vegetation types. The techniques fall into three main classes.

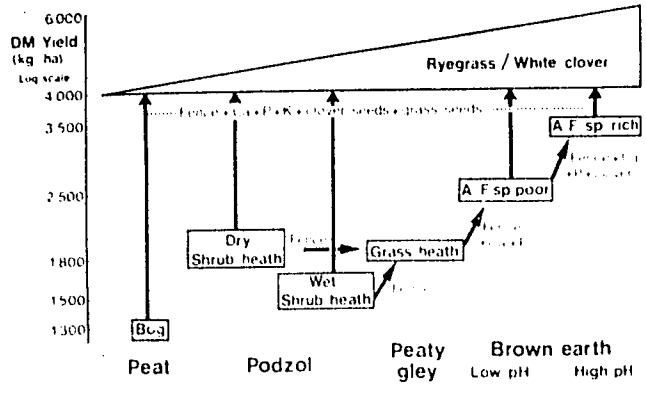

Figure 1. Vegetation successions needed to bring about pasture improvement.

Improve Utilization of Existing Vegetation

Because the stocking rate in traditional systems is set by winter carrying capacity there is marked under-utilization of the herbage dry matter present in the growing season. Eadie and Cunningham (1971) have estimated utilization to be no more than 20% on average with many systems falling well below this level. There is considerable scope to make better use of the existing dry matter by controlling grazing with the aid of fences, by increasing stocking rates and/or by mixed stocking, i.e. following sheep with cattle when possible since the latter are less selective grazers. Thus the only financial input need be a fence, although it is likely that the cost of extra stock and additional veterinary services may also be incurred. The applicability of this technique differs in degree between the various plant communities.

Both variants of acid grassland respond well to the low cost improvement provided by a fence (Eadie *et al.*, 1976a). Grass heaths dominated by either *Nardus* or *Molinia* respond less well to this simple treatment (Eadie *et al.*, 1976c). Bog vegetation on the deep peat soils shows little favorable response to extra grazing (Grant *et al.*, 1976) and improvement here demands the application of lime and fertilizers and the sowing of grass and clover seeds. Similar considerations apply to the wet shrub-heath and probably to the dry shrub-heath dominated by *Calluna vulgaris* (heather). Until recently little was known of the nutritional qualities of this vegetation

or its response to utilization. Work at the Hill Farming Research Organization now indicates that heather vegetation can do little more than provide a maintenance or near maintenance diet for sheep and that grassy or grass/clover areas are needed within the heather to provide adequate nutrition for lactation for single lambs and for ewe body weight recovery (Grant and Milne, 1973; Milne, 1974). However, these workers have shown that the heather plant can be utilized more efficiently (up to 40% of present season's shoots) without detriment to its own growth and persistence. Many farmers appreciate having this vegetation because of its usefulness in winter.

The principles of good heather management by regular burning to maintain a high proportion of present season's shoots are well known and a new guide for farmers is about to be published (DAFS, 1976). Some difficulties have arisen in the past over the application of this knowledge because of conflict between sporting and agricultural interests.

Improve Production and Quality

Improved utilization as described has the consequence of improving quality and quantity *per se*, because more nutrients are recycled through the grazing animal. In addition, since more young green leaves are exposed to sunlight, photosynthesis, and hence growth, can proceed more efficiently. However, the process of improvement can be further enhanced by a variety of treatments, e.g. burning, cutting, liming, adding fertilizers and applying herbicides before sowing of seeds is needed.

The coarser grasses, e.g. *Nardus*, can be discouraged by use of low doses of Dalapon (Haggar, 1976); this treatment can be cost effective if better grasses are available to take its place. Communities of acid grassland dominated by *Pteridium aquilinum* (bracken) can be improved by use of herbicides such as Asulam which controls the bracken. This weed has been controlled in the past by cutting and plowing but not all sites are amenable to the latter treatment. Recent work by Davies (1976) suggests that it may be possible to cover the cost of the chemical treatment by the value of the extra production from the underlying vegetation.

There is little evidence even with acid grassland that hill swards respond with extra dry matter production to applications of lime and phosphate alone, unless sward composition is altered markedly. The addition of nitrogen can bring about some increased production in all but *Molinia*-dominated swards (Milton, 1940; Hunter, 1962) but Davies and Munro (1975) have shown that *Agrostis-Festuca* and *Molinia* communities are far less responsive to nitrogen than introduced ryegrass/white clover swards.

Significant increases in production only follow the introduction of white clover and grass seeds to supplement the indigenous vegetation. Recent work at HFRO (Eadie *et al.*, 1976c) illustrates many of these points well. Three sward types (*Agrostis-Festuca* on brown earth pH 5.8, *Molinia/Nardus* on peaty podzol pH 4.0, and *Nardus* on peaty podzol pH 3.8) were enclosed, cut and burned, and in the case of the *Nardus* site, treated with Dalcon, in early spring. Five treatments were then applied:

1. Control.
2. Lime (6.3 MT/ha).
3. Lime and phosphate (1.25 MT slag/ha).
4. Lime, phosphate and white clover seed (1.40 kg S100/ha, 0.84 kg Kent Wild White/ha.
5. Lime, phosphate, white clover and grass seed (22 kg perennial ryegrass/ha), plus 40 kg N/ha at time of sowing.

The plots were grazed by wether sheep at three times in the year (May–June, July–August, October–November) over a period of four to five years; the stocking rate per plot being judged by the measured quantity of available dry matter at the start and finish of each period and the grazing pressure equated in terms of dry matter per sheep per unit area. Relative production was assessed in a number of ways, but the mean number of grazing days alone is shown in Figure 2. The three swards all responded significantly to treatments 4 and 5 but only the *Agrostis-Festuca* to treatment 2. The number of grazing days was always greater in the *Agrostis-*

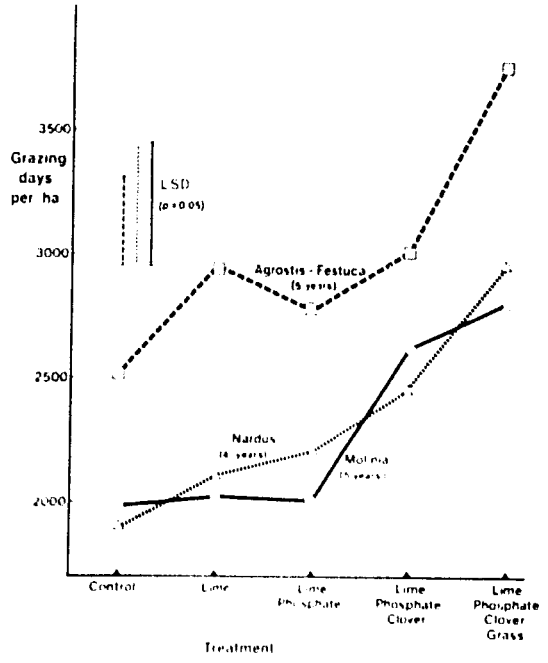

Figure 2. Effect of sward treatment on the number of grazing days per hectare over three grazing periods per season supported by three contrasted vegetation types in southern Scotland (Eadie *et al.*, 1976). Mean results for four or five years.

TABLE 2. Model scheme for improvement of hill land by replacement of indigenous vegetation

Process	Factors or Activity	Input to Land (per ha)	
Plan	Management and economic strategy	*Prior to sowing*	
Survey	Soil, vegetation, "wetness," access, aspect	Lime	2.5–7.5 t
Select site	"Ideal" = low altitude, drier mineral soil	Phosphorus	30–80 kg P
Enclose	Cheap, effective and long-lasting fence	*At or near sowing*	
Destroy indigenous	Burn, cut, graze + cattle, herbicide	Nitrogen	40–100 kg
		Potassium	60–120 kg
Lime	Reduce acidity (pH > 5.5)	Phosphorus	40– 60 kg
		White clover	2 kg
Fertilize	Phosphate, potassium, nitrogen	Perennial ryegrass	24 kg
		Timothy	8 kg
Cultivate	Prepare seed bed with adequate moisture	or Cocksfoot	8 kg
Sow seed	White clover (with *Rhizobium*) and grass	*The spring after sowing*	
Utilize	Avoid grass heading and overgrazing in autumn and spring	Nitrogen	0–40 kg
Maintain	Grazing control, lime and phosphate	*3–7 years post sowing*	
		Lime	5 t
		Phosphorus	60 kg P

Festuca than the other two swards. On the assumption that a sheep consumes about 1.4 kg DM/ha/grazing day the total yield of dry matter on the best sward was approximately equivalent to an annual production of 5 250 kg/ha.

Despite the well-illustrated benefit of introducing white clover into acid grassland swards this is still not easy to do technically and will be discussed further in a later section.

Replace Existing Swards with Sown Plants

It is possible, on all but the wettest, steepest or rockiest hills, where access is available, to replace the existing vegetation with introduced plants if cost is no limitation. However, since the latter condition rarely applies, a great deal of effort has gone into finding the cheapest and easiest methods commensurate with results (i.e. cost/benefit analysis) for a range of site types. Although model improvement schemes for all the main vegetation types described earlier can be selected from the processes listed in Table 2, this does not mean that all subjects are equally deserving of attention or that the responses are identical. It should be evident that major capital investments of this type must be directed at those site types with the greatest potential to respond to the treatment.

RELATIVE COSTS OF DIFFERENT TECHNIQUES

Many combinations of the main agronomic techniques used to bring about pasture improvement are possible in practice and the relative cost of just a few of the principal groups are shown in Table 3. Present legislation in the UK allows the farmer to claim a 50% grant against such investments so that the net cost to the farmer is half that indicated by the Table. It is hoped that EEC regulations will allow this level of support to continue.

TABLE 3. The relative cost of hill land improvement techniques used in the United Kingdom

Fence to Control Grazing	Cost Relative to Fencing
Alone	1.0[1]
+ Herbicide Dalapon (to reduce *Nardus*)	1.2
or Asulam (to control *Pteridium*)	1.4
+ Lime and phosphorus	1.9
+ Lime, phosphorus and white clover seed	2.1
+ Lime, phosphorus, white clover and grass seed	
with oversowing	3.0
with light cultivation	3.2
with plowing	3.4

[1]The base line was taken as £78, i.e., the gross cost per ha of enclosing an area of 8 ha with a fence costing 55 pence/m.

PROBLEMS

Despite much experience with these techniques and their application, some agreed and some controversial problems remain for discussion and further research. These are described briefly below:

Drainage. This is not mentioned in the model scheme (Table 2), although it is indicated under site selection that the drier of the wet areas should be used. By contrast many advisers place drainage at the top of their list of actions. However, the hill farmer who wishes to improve production can often achieve this by extending improvement into the accessible drier areas of indigenous vegetation with-

out an expensive drainage scheme. Hill farmers who have no drier areas may need to remove excess surface water by a few well-placed open drains (£3/ha). The cost of underground systems (up to £500/ha) with tiles, polythene pipes and infill is rarely justified in the hill environment although if the process moves land from a very low to a very high production capacity which is effectively utilized, it may sometimes be equated to the purchase of lowland. The role of drainage is different for a lowland farmer who has to seek to increase production from areas otherwise capable of a high level of production.

A further option which has been successfully applied on the west coast of Scotland (Nicholson *et al.*, 1968; Eadie *et al.*, 1976b) is to improve only the drier portions of a large area of wet vegetation on a mosaic pattern, the whole area being fenced. Because the quality of herbage on the improved areas is much greater than that of the indigenous vegetation it is preferentially grazed by sheep so that the required degree of strategic grazing control is achieved by the outer fence around the whole designated paddock.

Fences. Despite general acknowledgment that the first step in hill land improvement is the provision of a fence there has been little research into fence design in the UK. Most of the stimulus to develop and cheapen new fence designs has come from New Zealand. The cost of traditional fencing (posts and wire) is now excessive but the provision of high tensile wire of thinner gauge enables novel spring and electric fencing to be designed (Armstrong, 1975; Gilman, 1975). Further efforts to provide inexpensive but efficient barriers of long life are required.

Cultivation. This is needed both to reduce competition from indigenous species and to prepare a suitable seed bed. Plowing, discing, rotovating and harrowing have all been used successfully on brown earth and well-drained peaty podzol soils. It is not yet possible to define the "ideal" seed bed or acceptable deviations from the ideal, but the following are important general characteristics to be aimed for:

Well-drained brown earth—complete suppression of competition from indigenous plants and a fine tilth in soil surface but with general firmness; poorly drained brown earth—complete suppression of competition and good water penetration properties; dry peaty podzol—firmness; wet peaty podzol—lack of surface water and ability to carry out timely operations; and peat—lack of surface water (no cultivation is usually required other than treading in by sheep).

Problems which can arise are puffy or loose seed beds, too much trash on the soil surface, chunks or pads of peat overlying but separated from mineral layers, puddled or smeared surfaces, and the active regeneration of indigenous plants, particularly on the brown earth sites. Machinery has not been designed specifically for hill conditions so that rotovators brought from lowland farms are sometimes not robust enough to cope with the stony or rocky conditions found in hill soils. Plowing, though much used on accessible areas in the past, particularly in Wales, is used more cautiously now following the appearance on many treated areas of *Juncus spp.* (rushes) from the exposure of buried seeds.

The need to introduce clover into existing swards has increased interest in the design and production of sod-seeding machinery. Prototypes are under development in England (WRO, 1974) and in Scotland (NIAE, 1974) respectively and both rely on the slit principle.

Time of Sowing. As might be expected with the wide variation in climate in the hills of the UK a broad range of recommended sowing times exists, varying from March to August. Depending on region, farmers are told to avoid May and June which tend to be dry. Without more accurate predictions of weather than are possible at the present time the aim in choosing a sowing date is to have sufficient soil moisture, good conditions for rapid growth and no frosts. In general, this means as early in the spring as possible. An attempt to examine this subject more closely is in progress (Rogers, 1976) and early results suggest that there may be advantages to sow in the autumn, particularly for grasses, but also for white clover. The plants should be sufficiently established to survive the winter. They are then able to grow rapidly as soon as conditions for growth return in the following spring

Starter Fertilizer—Amount and Time of Application. Opinions differ as to the amount of fertilizer nitrogen needed, and the best time to apply it in relation to sowing. Advisers and farmers in Scotland tend to suggest no more than 40 kg N/ha, while in Wales they recommend 80–120 kg N/ha. Suggestions as to when it should be applied vary from three weeks before, the same time as, or up to nine weeks after sowing. This spectrum of opinion reflects the contrasting reasons for adding starter N fertilizer. In the generally N-deficient soils it is needed to give the grass plants sufficient N for establishment and yet there must not be so much as to interfere with nodulation and N fixation by the white clover. There is evidence to suggest that N fixation of established white clover treated with 80 kg N/ha is only 23–30% of that in plants with no added N (Moustafa *et al.*, 1969). Investigations to resolve these issues are currently in progress at HFRO (Haystead, 1976).

Response to Fertilizer. The response of indigenous hill vegetation to application of lime and P is poor

in terms of dry weight (Fig. 2) although the content of Ca and P in the herbage may be enhanced. Response to added N is variable; Davies and Munro (1974) found a very poor response with *Agrostis-Festuca* when compared with ryegrass growing on a brown earth soil. Thus, there is more interest in determining the response of ryegrass, and especially white clover, to fertilizers over the range of hill soil types.

Recent work with white clover grown in pots of deep peat, peaty podzol and brown earth soils at HFRO (Rangeley, 1976) have shown that there was no increase in dry matter production of clover shoots in any of the soils when the N level was increased from 0-80 kg N/ha. Significant responses to P (0-160 kg P/ha) and K (0-320 kg K/ha) and a positive interaction between them was observed in all the soils; the magnitude of response was greatest in the deep peat and least in the brown earth soil. The interaction between P and K is illustrated in Fig. 3 and, if confirmed in the field, may merit a closer cost/benefit analysis to see if the quantity of K (40-80 kg K/ha) usually recommended for soils of this type with a P application of 60 kg P/ha should be increased.

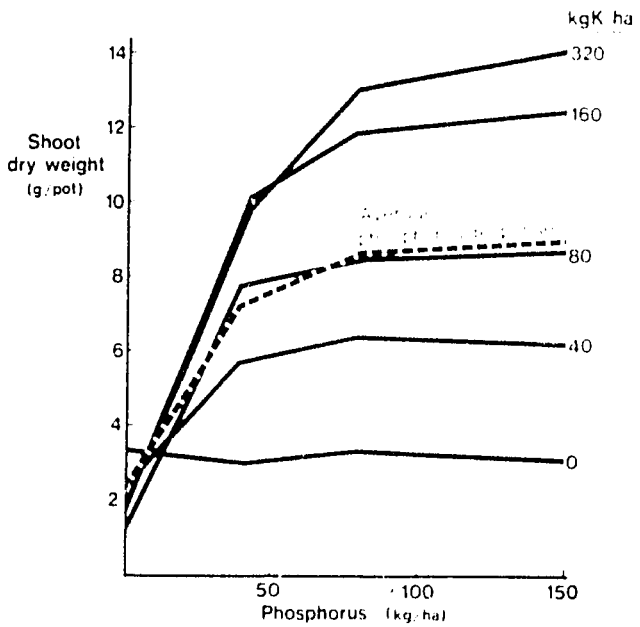

Figure 3. The response of white clover to potassium and phosphorus when grown for nine weeks in pots of dry peat soil (Rangeley, 1976).

Trace Elements. Hill soils derived from acid igneous rocks, sandstones or peats are often low in trace elements such as Cu and Co which are required for satisfactory growth and health of plants and/or animals. Since the availability of Mo which can induce Cu deficiency rises with liming, and because of the dilution effects on the small amount of the trace elements caused by growing more productive plant species, care must be taken when improved pastures are formed with liming on soils known to be low in extractable Cu and/or Co. Affected animals can be treated directly by drenches, or grazing management can ensure they are not left for too long a period on the improved sward. Treatment of the soil and/or vegetation with Cu (20 kg/ha) and Co sulphates (2 kg/ha) is advocated but this has been shown to have little effect on the Cu content of grass; white clover shows a bigger response (Mitchell, 1972). Since Cu in the diet of grazing sheep in amounts greater than about 20 mg/kg dry matter is toxic these procedures must be used with caution.

To optimize nitrogen fixation by *Rhizobium* in its symbiosis with white clover it may also be necessary, particularly now that slag is no longer readily available, to add small amounts of Mn, Mg, Mo, B and S to some soil types.

Inoculation of White Clover. Many hill soils have either no *Rhizobia* or small numbers of largely ineffective strains (Holding and King, 1963; Mytton, 1975). Responses to inoculation have been recorded on the former soil types (Mytton, 1975) and a major collaborative series of trials in Great Britain is currently investigating responses in soils of the latter type. Only one commercial firm in the UK markets inoculated clover seed although this is of the pre-inoculated type which is not always ideal (Thompson, 1976). Other firms provide inoculum on request but this is usually of Australian or Dutch origin and no tests have been carried out to establish its suitability for conditions in the UK. As yet there is no official system for monitoring the quality of inocula.

Other Legumes. White clover has some disadvantages; it requires relatively high pH and P levels in the soil; its growing season is shorter in both spring and autumn than grass; the total amount of dry matter produced is less than with grass and it is difficult to conserve for silage because of its high water content and for hay because its leaves become brittle on drying. Cases of bloat when cattle are grazed on hill pastures rich in white clover are rare and there is no information in the UK that the estrogenic content has a significant effect on the fertility of young stock.

The selection of white clover cultivars to overcome these disadvantages could be of great benefit. Other papers at this Symposium will deal with this aspect in more detail.

Alternative legumes such as *Lotus sp.* are under investigation (Charlton, 1973, 1975), and it appears that some of the better varieties bred in New Zealand may have promise.

Grass Species. This subject will be dealt with by Breese (1976), but one aspect is relevant to the present discussion.

As described in Table 2, the grass most commonly sown to accompany white clover is perennial ryegrass with smaller amounts of timothy, cocksfoot and possibly red fescue. Ryegrass has a high fertility requirement to maintain a reasonable level of production. Pastures sown to perennial ryegrass rarely remain pure and other grasses are able to establish. For these reasons some authors (Elliott *et al.*, 1974; Herriott, 1975) have suggested that a grass type which thrives in hill situations at low fertility levels (e.g. *Holcus lanatus*) should be encouraged or sown to accompany white clover instead of ryegrass. While *Holcus* establishes quickly, has early spring growth and produces almost as much dry matter as *Lolium*, little is known of its value to livestock. Most reports are observational in character but they suggest that stock will only consume *Holcus* when all other sources of feed are exhausted. Further, little is known of its properties as a companion grass to white clover from the point of view of competition.

Pioneer or Nurse Crops. For shallow light soils it has been suggested that the growing of a "pioneer" crop, such as rape or turnips, which is grazed off before attempting to establish the final sward, is of benefit. The resultant build up in fertility and in soil compaction leading to rapid establishment of sown grasses and clover, together with the value of the pioneer crop, is reported to outweigh the extra cost of the additional steps in the land improvement process in some situations. The use of kale or rape to "nurse" newly sown grass/clover swards is also advocated from time to time. The advantage claimed here is that some fodder is provided for stock while the pasture is becoming established. However, the extra competition to the white clover makes the latter a risky process.

Maintenance of Improved Pasture. There is general awareness that improved pastures formed at considerable expense need to be effectively managed by careful control of grazing and by the maintenance of fertility and lime status adequate to prevent rapid deterioration (Reith, 1973). On average 5 MT lime/ha 2–5 years and 1.25 MT basic slag (10–13% P_2O_5) 2–4 years after the initial application are required. However, many farmers wait until signs of sward deterioration are apparent before taking action. More quantitative information is required on the amounts of lime and phosphate needed in different environments to maintain adequate levels of fertility for white clover and the better grasses.

RESPONSES TO HILL PASTURE IMPROVEMENT

Little published generalized information is available on levels of utilization, production and quality of herbage to be expected from indigenous and improved hill swards because of the numerous factors which can influence responses, but likely levels are given in Table 4. The data illustrate the low levels of utilization of unimproved hill vegetation

TABLE 4. Estimated levels of utilization (%), yield (kg DM/ha), and seasonal digestibility range (DDM %) for the main hill vegetation types and the possible response to improvement. Data for a lowland permanent pasture on mineral soil are shown for comparison. (Based on Jones, 1967; Black, 1968; Eadie and Cunningham, 1971; Grant and Milne, 1973; Eadie *et al.*, 1976)

	System of Grazing Management								
	Traditional (little control)			Improved Traditional (moderate control)			"Two-pasture" (good control)		
Indigenous Sward	Unimproved						Improved to Ryegrass/White Clover		
Type	Utilization	Yield	DDM	Utilization	Yield	DDM	Utilization	Yield	DDM
Lowland permanent pasture	60	4 000	75–55	70	4 500	75–60	80	7 500	80–[illegible]
Acid grassland (A/F spp. poor)	20	2 500	72–63	30	2 800	75–66	70	6 000	78–66
Dry shrub-heath	15	1 800	58–52	20	2 000	69–62	70	5 000	78–66
Wet shrub-heath	10	1 500	70–62	12	1 600	71–64	70	4 500	78–66
Bog	5	1 300	66–40	7	1 400	66–50	70	4 000	78–66

found in traditional systems, particularly by comparison with lowland pasture, and the responses to increased grazing pressure and to the complete replacement of the indigenous vegetation. They also illustrate that for short times at least the quality of the herbage from indigenous swards, as indicated by the proportion of digestible dry matter, can be relatively high.

The only sure test of the benefits to be obtained from hill pasture improvement of the types described here is to assess the amount and quality of animal products and the impact on farm income. Some examples of economically successful application of hill land improvement techniques in contrasted regions of the UK are provided at this Symposium by Eadie *et al.* (1976a, b) and Maxwell *et al.* (1976).

STRATEGY OF IMPROVEMENT

Many of the principles of hill land improvement as detailed here have been known for years (Stapledon, 1933; Young, 1936), but frequently the benefits were lost or much reduced because no clear policy of utilizing or maintaining the improved pasture was available. Thus, before commencing any hill land improvement, the farmer should consider the following:

1. There must be a need for better quality or a greater quantity of herbage. The use to which this will be put within the farming system must be defined in such a way that the system of grazing management will prevent the improved sward from deteriorating rapidly.
2. The amount of finance available and the responses required to service it should be known.
3. A survey of the soil and plant community types present on each particular farm unit should be made. Physical details of slope, aspect and accessibility for vehicles and for stock can be noted at the same time. This enables the areas with greatest potential for response to improvement, as indicated earlier in this paper, to be identified.
4. The consequences of intensifying animal production in hill areas (i.e. buying in new stock, moving animals to previously under-utilized areas, and higher stocking rates on smaller areas of improved land) must be anticipated and guarded against at this early stage.
5. The economic consequences of the investment, not forgetting the additional costs of looking after more animals, e.g. provision of water, preventive veterinary medicine and including the cost of maintenance dressings of fertilizer should be assessed at the planning stage. Economic models using computers enable many of the possible options for improvement (its extent and scale) to be explored rapidly (Maxwell *et al.*, 1976).

APPLICABILITY TO OTHER PARTS OF THE WORLD

While the soil, vegetation and climatic conditions on hills in the UK are almost unique, the principles of pasture improvement described here should be generally applicable. Thus, both the slow change of herbage quality and species composition caused by increased and controlled utilization and the rapid change in production which follows reduction of competition, raising of soil fertility and the sowing of seeds of a legume and good quality grasses, should be possible in most environments. The precise procedures to be adopted will vary from region to region, but in the main, the complications which arise from the presence of the matt of partially decayed plant residues in UK rough grazings do not arise. Some hilly regions, e.g. the Alps and Scandinavia, can only be grazed in summer but during that period soil and climatic conditions already permit rapid growth of high quality pasture. Hill soils in much of New Zealand and in Africa are unglaciated and accordingly are deeper and richer in bases than UK soils. Conditions in Australia, Asia and the USA, which will be described in more detail elsewhere at this Symposium, are probably intermediate between these extremes. Thus, while there is general agreement that all hill land can be upgraded at a cost and although detailed recipes of hill land improvement may differ between regions, two of the key tenets undoubtedly applicable to all hill lands are the need for a rigorous cost/benefit analysis before commencing a scheme and the use of legumes to provide N and a nutritious diet for stock.

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DISCUSSION

W. C. Templeton (Pennsylvania, USA). I believe you use some N at the seeding of white clover, at least under certain conditions. If so, would you give us the rationale for this?

Newbould. We are using a starter dressing of about 40 kg N/ha, although this varies with soil type and climate. The precise amount is an area of controversy with Munro and his colleagues in Wales who tend to use higher rates of about 100 kg N/ha. We are currently investigating this subject. Our evidence at the moment is that to optimize N fixation and clover growth we would do better without N or with very little, but a small amount is needed for the grass since we are trying to establish both grass and clover. An application of 80 kg N/ha has been shown to reduce N fixation by clover to only about 20% of what it would be without N. Thus, it is necessary to judge the level of nitrogen very carefully to achieve the dual objectives of optimizing N fixation by white clover and obtaining rapid establishment of grasses.

J. Balasko (West Virginia, USA). Have you been able to replace ineffective *Rhizobia* in the field with effective *Rhizobia*?

Newbould. The short answer is no. We are currently investigating aspects of this subject in a collaborative series of trials with the Edinburgh School of Agriculture, the three Scottish Colleges of Agriculture, Munro at the Welsh Plant Breeding Station, and three of the experimental husbandry farms in the Agricultural Development and Advisory Service of England and Wales. A series of trials with identical treatments were run at 15 sites in 1975 and 7 sites in 1976. In 1976 we concentrated on the drier mineral soils, because in 1975 we observed significant agronomic responses to inoculation on the deep peats, a trend to a response on the peaty podzols, but little or no effect on the brown earth soils. Unfortunately, drought made it a very difficult year for doing clover inoculation experiments. No agronomic responses were noted, but despite this we recorded big effects of inoculation on nodulation patterns. Dr. Holding, microbiologist from the Edinburgh School of Agriculture, has used genetic markers on the rhizobial strains and we know that 60% of the nodules on the clover plants at two of the brown earth sites were formed by introduced effective *Rhizobia*. The highly significant microbiological response to inoculation in 1976, but not in 1975, on the mineral soils may be due to the increased number of *Rhizobia* on each clover seed in 1976 (about 12 000 rather than 3 000 per seed). However, it appears that we still have a long way to go to achieve predictable agronomic responses by white clover to inoculation on the brown earth soils.

G. Jung (Pennsylvania, USA). I have two questions: I would like to know if you or your colleagues have looked at Mo with regard to clover growth and, secondly, have you made any advances in your attempts to select for early growth of clover in the spring, which I was told about when I visited Scotland recently?

Newbould. We had expected that we would have a requirement for Mo on the deep peat soils and to offset any problems we used a trace element cocktail which included Mo in all the trials I have just described. In earlier work we compared treatments with and without Mo but no response was observed. However, it is well authenticated in the literature that clover needs some Mo. Of course, a number of the responses that have been reported from Australia and New Zealand may be due to the sulphur in the Mo salts.

The work to select clovers which grow early in the spring is still in progress. Research on plant breeding and selection in Britain is currently being rationalized and, although the project started at the Scottish Plant Breeding Station under the direction of Mr. R. N. Whitehouse it may shortly be transferred to the Welsh Plant Breeding Station. Fourteen hundred types of clover from all over the world were collected, and last winter the 200 that grew early at 300 m altitude on a hill near Edinburgh were noted. A further reduction to about 20 types best able to grow early in the season, and hence to tolerate cold conditions, is proposed before detailed growth room comparisons commence. Any outstanding low temperature tolerant clover genotypes will then be matched with strains of *Rhizobia* which have been selected for low temperature growth also; the latter project by Miss D. M. Vernon is in progress at Hill Farming Research Organization. One point briefly, we did include Caucasian white clover, *Trifolium ambigium*, in this comparison. We had heard good reports of it from Australia but it has not done at all well in our hill environment.

K. F. O'Connor (New Zealand). It seems to me on appearances that, because you can cultivate, you do cultivate. I would ask, is not your cultivation creating problems which you then have to do more work to get out of? Things like pre-sward treatment, seed coating, specific timing of your sowing in relation to soil moisture and adverse conditions for germination—wouldn't they take a big whack out of what the bank manager would like to see you get?

Newbould. I agree with you in theory; cultivation is expensive and it sometimes creates the problems you describe but I think when you see our conditions you will realize why we can't do without it in some situations, e.g. to control the indigenous vegetation on our brown earth soils. We would often like to use paraquat alone to kill indigenous vegetation and sow into the dead sod. Now, that's fine if there's something green there to absorb the chemical, but our problem often is that with a late spring towards the end of May there is no green vegetation. We may have sprayed late on in the autumn of the previous season—we then hope to get regrowth so we can spray again in the spring. The only option that remains to control growth of the indigenous grasses is cultivation. On one of my clover trials the clover was sown into apparently bare ground but shortly after sowing we had a rain storm and a weed grass (*Holcus lanatus*) came up and absolutely swamped the clover. This problem might have been avoided if I had cultivated just prior to sowing.

O'Connor. Why not use stock to graze it down?

Newbould. Yes, we've tried stock and they do a good job in some situations, but you still get tussocks or some grasses left which then regenerate. Our indigenous vegetation on the hills only grows for five or six months as compared to ten months in New Zealand but when it does grow in the spring it usually starts growing very, very rapidly and soon becomes very competitive to sown clover and grass seedlings.

13.
Hill Land Improvement in Eastern United States

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The hill lands of the eastern United States represent the largest potential forage resource area of the nation. If we include land east of a line from east Texas through Minnesota with little or no potential for row cropping on a commercial scale, the total approaches 100 million acres (40 million ha) (USDA [1971b]).

In general the soils and climate are favorable for good forage production. Except for prairie areas, largely in the midwest, the climax vegetation is forest, described by Barrett (1962) as the eastern deciduous forest. It has one of the most complex and variable aggregations of woody vegetation in the temperate regions of the world. The northern half of the area is characterized by gray-brown forest soils and the southern half by red and yellow zonal soils. It has a continental climate with warm summers and cold winters (USDA, 1941). The more southerly portion has open winters and relatively little or no snow cover. Rainfall is generally adequate for good forage production, ranging from 30 to 60 inches (760 to 1 500 mm).

THE APPALACHIAN-OZARK REGION

In the center of the eastern hill land area is the east and central general farming and forest region as classified by the USDA Soil Conservation Service (Austin, 1972). This region includes the Appalachian Mountains, valleys, and dissected plateaus, as well as the Ozark highlands. This region doesn't encompass all of the hill lands of eastern U.S., but it is the largest contiguous hill land area, and I will characterize it more fully as described by Austin (1972).

The annual precipitation ranges from 35 inches (860 mm) along the western edges to 60 inches (1 500 mm) or more on some of the higher eastern mountains. The frost-free season is 180 to 220 days over much of the region, ranging from 150 days in the northeast to 240 in some southern valleys. The elevation of the valley floors ranges from 300 to 1 000 feet (90-300 m) and the plateaus and peaks from 1 000 to 3 500 feet (300-1 100 m). Soils derived from sandstones and acid shales are extensive on the mountain slopes and dissected plateaus. Red-yellow podzolic soils are found on limestones and more deeply weathered shale. The steeply sloping areas, about half of the region, are mainly forested. A large part of the nation's coal is mined in this region.

Small general farms are typical of the region with some large dairy and livestock farms on more favorable sites. Corn, small grains, and hay are the most extensive crops. The topography of the hill lands

has impeded the development of large farms. Coltrane and Baum (1965), in their economic survey of the Appalachian region, reported that the average size Appalachian farm was 106 acres (43 ha), with much of the cultivatable land in small isolated tracts or on rough terrain that cannot be farmed efficiently with modern machinery designed for large-scale agriculture. Shaudys and Sitterley (1957), in a study of 131 beef farms in the southeastern Ohio hill lands, found that the farms averaged 269 acres (109 ha), one-third in crops, one-half in pasture, and the remainder in woods. In a recent study, Sitterley (1976) found that the average size farm in the 22 eastern counties in the Appalachian plateau of Ohio was about 160 acres (65 ha). About half of the area of these farms was in forest.

CONVERTING FORESTS AND BRUSHLAND TO GRASSLAND

The eastern hill lands have millions of acres of grazed forest and brush that could be converted to forage (USDA, 1971a). Many farmers have found it expedient to allow their livestock to graze woodlands rather than to go to the expense of fencing off the pasture areas. Converting such areas to grassland would include removal and control of the woody species, fertilization, reseeding, and grazing management, including fencing out the areas best utilized for timber production.

Ahlgren *et al.* (1946b) reported that over half of the area in farm woodlands in the United States was grazed by livestock. Their study of grazed woodlands in the hill lands of southwestern Wisconsin showed that renovated and untreated open pastures produced an average of 3 210 lb/acre (3 598 kg/ha) and 1 453 lb/acre (1 629 kg/ha), respectively, compared with 276 lb/acre (309 kg/ha) for woodland pastures, with slopes of 15 to 35%. Not only was grazing of woodland detrimental to the trees and considered undesirable forest management (Den Uyl *et al.*, 1938; Den Uyl, 1945), but also cattle lost substantial weight while confined to woodland pastures (Den Uyl and Day, 1934).

Early pasture improvement in the United States consisted largely of cutting brush (Brown and Slate, 1929), a perennial task to prevent the pasture from reverting to woodland. If fertilized and seeded to vigorous forage species, brush control became much less of a problem. Although burning of pasture in early spring was used to kill and remove brush (Brown and Slate, 1929; Aldous, 1929), Graber (1926) found that burning of a Kentucky bluegrass (*Poa pratensis* L.) pasture resulted in markedly less forage and root production compared with not burning. Weeds came in thickly on the burned plots, particularly the plots burned in May.

Stuckey (1952) described the plant succession on abandoned land in Rhode Island and the pasture renovation needed, including brush removal, to reclaim the fields for pasture. The results were excellent, but she commented that the labor of removing the brush by hand would be a deterrent to most farmers to improve the pastures. In an Indiana study (Stalder and Robertson, 1952), pasture improvement costs increased markedly if bulldozing was necessary to remove larger trees and brush and to fill large gullies, but land value also increased proportionately. In an Ohio study (Miskell *et al.*, 1968), the use of a large bulldozer was the cheapest method of clearing brush and trees from hill land in southeastern Ohio if a charge for labor was made (Table 1). However, as pointed out by these researchers, if labor was readily available with no alternative use, the cost of clearing land by hand would be the least expensive in out-of-pocket costs, but the most time-consuming. Clearing land is costly and will not pay on all types of hill land. Clearing should generally be done only on land that is not too steep, rough, or rocky for mowing, spraying, or fertilizing, and where good forage production would be expected. Certainly, the alternative use for forest production should be considered.

TABLE 1. Cost per acre for clearing brush and trees, Miskell *et al.*, 1968

Method	Total Cost per Acre ($)
Chain saw and ax	107.75
Brush hog	98.50
Small crawler tractor with blade	74.25
Large bulldozer	30.75

The development of herbicides for brush and scrub tree control to replace or supplement cutting, girdling, bulldozing, and burning has greatly reduced the costs and problems of eliminating woody plants. As early as 1929, pasture researchers in the U.S. were trying various materials to control brush, using chemicals such as sodium chlorate, zinc chloride, and sodium arsenate (Aldous, 1929).

As shown by Martin *et al.* (1954), such herbicides as 2,4-D (2,4-dichlorophenoxyacetic acid), 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), and ammate (ammonium sulfamate) not only initially controlled a wide range of the woody species, but also reduced the amount of sprouting which was a problem with only cutting off many woody species. The use of herbicides provides flexibility in brush and tree control from small-scale hand spraying to power ground spraying and aerial spraying for large-scale operations. Aerial applications by plane or helicopter are useful where ground spraying cannot be done or can be accomplished only with great difficulty

because of the density and size of the woody vegetation or roughness of the terrain. Aerial application requires relatively large areas to justify its use and is of limited value for the small farms typical of the eastern hill lands.

Wendel (1966) showed that oaks (*Quercus* spp.) and a number of other woody species could be partially or completely controlled by aerial applications of 2,4,5-T in a West Virginia study. Hickories (*Carya* spp.), pines (*Pinus* spp.), dogwood (*Cornus florida* L.), and hawthorn (*Crataegus* spp.) showed little or no damage from the herbicides. A study in the Missouri Ozarks showed the value of aerial application of 2,4,5-T to convert low quality oak stands to grass (Crawford and Bjugstad, 1967). Similar results with oak species were obtained by Elwell (1964) in eastern Oklahoma with aerial applications of 2,4-D, 2,4,5-T, and silvex [2-(2,4,5-trichlorophenoxy) propionic acid] with larger amounts of 2,4,D than of 2,4,5-T or silvex required to control those woody plants. Anderson *et al.* (1971) showed that brush control with herbicides was most effective in early stages of growth and that follow-up spraying was usually necessary. As they pointed out, pasture brush often is a mixture of woody species, with a range in susceptibility to herbicides, with some species difficult to control (Table 2).

TABLE 2. Susceptibility of different species of woody plants in West Virginia to 2,4,5-T and 2,4-D (Anderson *et al.*, 1971)

Identify	Sprouting[a]	Susceptibility[b]
Blackberry, *Rubus* spp.	X	S
Black haw, *Viburnum* sp.		R
Blueberry, *Huckleberry* sp.	X	R
Black cherry, *Prunus* sp.	X	S
Dogwood, *Cornus* sp.		V
Crab apple, *Pyrus* spp.		M (V)
Elderberry, *Sambucus* sp.	X	S
Elm, *Ulmus* sp.		HR
Greenbrier, *Smilax* spp.		HR
Thornapple, *Crataegus* spp.	X	HR
Hickory, *Carya* spp.	X	M
Hickory sprouts (regrowth)	X	R
Juniper, *Juniperus* sp.		HR
Laurel, *Kalmia* sp.		HR
Locust, black, *Robinia* sp.	X	S
Maple, *Acer* spp.		HR
Oak, *Quercus* spp.		R (V)
Poplar, *Populus* sp.		M to S
Pine, *Pinus* sp.		R
Osage orange, *Maclura* sp.		S
Rose, wild, *Rosa* sp.		R
Sumac, *Rhus* sp		S
Sassafras, *Sassafras* sp.		S
Walnut, *Juglans*, sp.		S

[a]Indicated species developed new regrowth or sprouts.
[b]S = Susceptible, 80-100% control by one application.
M = Medium control, 50-80% control by one application.
R = Resistant, 25-50% control by one application.
HR = Highly resistant, 0-25% control by one application aerial spraying not effective.
V = Variable results.

FORAGE SPECIES IN OLD PASTURES

The dominant species in the region in permanent pasture with good levels of fertility is Kentucky bluegrass (Brown and Slate, 1929; Cooper, 1932; Gustafson *et al.*, 1934; Fuelleman and Graber, 1938; and Burns *et al.*, 1970). When the timber is first removed, soil fertility is generally favorable enough for Kentucky bluegrass and white clover (*Trifolium repens* L.), and the persistence of these two species will depend on the inherent fertility of the soil. Both species will eventually volunteer into favorable sites. Cooper (1932) described the succession of plant associations accompanying the depletion of pasture soils in New York, which he grouped as follows: (a) Kentucky bluegrass and white clover; (b) Kentucky bluegrass, bent grasses (*Agrostis* spp.), and white clover; (c) bent grasses and white clover; (d) bent grasses, sweet vernal grass (*Anthoxanthum odoratum* L.), and white clover; (e) sweet vernal grass; (f) sweet vernal grass and povertygrass (*Danthonia spicata* [L.] Beauv.); (g) povertygrass; and (h) herbaceous weeds, shrubs, and trees. In much of the region on infertile sites, broomsedge (*Andropogon virginicus* L.) also is found (USDA, 1970), often as a companion species to povertygrass (Garber *et al.*, 1946). Canada bluegrass (*Poa compressa* L.) is occasionally found on drier, less fertile sites than where Kentucky bluegrass is found (Braun, 1967). Cooper's grouping is based on soil pH values, but soil phosphorus and potash levels are important also, with Kentucky bluegrass requiring the highest levels of the groups listed above. Stuckey (1952) describes a similar plant succession for abandoned fields in Rhode Island.

IMPROVING OLD PASTURE

Lime and Fertilizer

Early pasture research in eastern United States showed the need for ground agricultural limestone (lime), phosphorus, potassium, and nitrogen for good forage production on eastern U.S. hill land pastures and for maintaining the desirable higher yielding species. These early researchers (Barnes, 1924; Wiggans, 1926; Brown and Slate, 1929; and Dorsey, 1929) were guided in part by earlier British pasture fertility studies. Barnes (1924) noted that the first response to applications of lime and P on infertile southeastern Ohio hill land pastures was a marked immediate increase in legumes, followed by an increase in Kentucky bluegrass, which took four years to develop into an optimum stand. Wiggans (1926), in New

York, got excellent response to lime and P but variable response to K. Nitrogen increased the total vegetation but decreased the clover in the sward. Brown and Slate (1929) in Connecticut showed the need for P for white clover production; lime alone increased the clover only slightly; K alone had little or no effect on the amount of clover. K with P, as with P and lime, resulted in some increase in clover over P alone. A combination of N, P, and K resulted in more Kentucky bluegrass than any other fertilizer combination. P alone or in combination with lime and K markedly reduced the amount of weeds in the sward by increasing the vigor of the sward. Other early research on lime and fertilizer on pasture included studies by Dorsey (1929), Odland *et al.* (1930), Brown (1933a, 1933b), Gustafson *et al.* (1934), Gardner *et al.* (1935), Robinson and Pierre (1938), Schaller *et al.* (1945), Smith *et al.* (1947), Robinson and Garber (1949), Haynes *et al.* (1950), and Midgley and Varney (1953).

Lime alone increased the carrying capacity of Kentucky bluegrass pastures in West Virginia, while P alone had less effect compared with no soil amendment, Table 3 (Robinson and Pierre, 1938). The combination of P and lime resulted in a further improvement in carrying capacity over P or lime alone. In a later study, Schaller *et al.* (1945) showed a marked improvement in the carrying capacity of bluegrass pasture with P and lime compared to no treatment (Table 4). The addition of K to P and lime increased carrying capacity slightly more, and adding N to K, P, and lime resulted in a small further increase.

TABLE 3. Effect of lime and fertilizer on carrying capacity of Kentucky bluegrass pastures in West Virginia (Robinson and Pierre, 1938)

Treatment	Carrying Capacity acres per cow
None	5.5
Lime	3.0
P	5.2
P and lime	2.5

TABLE 4. Effect of lime and fertilizer on carrying capacity of Kentucky bluegrass pasture in West Virginia (Schaller *et al.*, 1945)

Treatment	Carrying Capacity acres per cow
None	4.3
P and lime	2.3
P, K, and lime	2.0
N, P, K, and lime	1.8

TABLE 5. Dry matter yield response to pasture fertilization; Avg. 160 trials, 11 N.E. states (Robinson and Garber, 1949)

Untreated, lb/A	1091
Treatment	% Yield Increase
Lime	186
P	375
K	302
N	754
Lime, P, K	863

Robinson and Garber (1949) summarized a number of pasture fertilization studies from the northeastern states of the U.S. (Table 5). The use of lime, P, K, and N alone each gave a substantial percent increase in dry matter yield over no treatment. The use of N gave a much greater increase than lime, P, or K by stimulating the grass production. The largest increase was from applying lime, P, and K, which resulted in a marked response of the legumes, which in turn provided an improvement in grass production.

Beaumont (1932) summarized the early pasture fertilizer studies as follows: (1) lime was generally the first limiting factor; (2) P was deficient in most pastures; (3) response to K was variable and K was not generally as deficient as P; and (4) response to N was greatest in pastures that were largely grass and least in pastures that were largely clover, as would be expected. A sampling of soil test results from unimproved hill land pastures in Ohio is shown in Table 6 and illustrates the reason for the variable results as discussed by Beaumont. The pH values

TABLE 6. Soil test data from unimproved pastures in southeastern Ohio, (Ohio Agr. Res. and Dev. Center data, 1976)

Location*	Site	pH	P	K	Ca	Mg
			lb. available per acre			
NAEW, Coshocton Co.	0	5.4	16	141	1160	180
EORDC, Noble Co.	18	5.2	19	204		
	21	5.4	36	244		
	28	5.6	22	232		
	30	6.2	36	300		
	35	5.6	20	228		
	36	5.9	14	180		
	52	4.7	53	266		
	67	4.5	15	156		

*North Appalachian Experimental Watershed and Eastern Ohio Resource Development Center.

vary widely, ranging from 4.5 to 6.2; the level of available P is generally low; and the available K level varies greatly, from 141 to 360 lb/acre (158 to 403 kg/ha).

Jung *et al.* (1967), using permanent pastures with 20 to 30% slope, demonstrated the feasibility of applying fertilizer with fixed-winged aircraft to West Virginia hill lands. Peters and Lowance (1974) reported that fertilizing bluegrass with N, P, and K effectively controlled broomsedge as did seeding Kentucky 31 tall fescue (*Festuca arundinacea* Schreb.) into a pasture infested with broomsedge and fertilizing with N, P, and K. Grazing also appeared to aid the elimination of broomsedge.

Current research on U.S. forage fertilization is reviewed in the recent forage fertilization symposium publication (Mays, 1973). With the availability of soil testing service by the cooperative extension service in most states, forage fertilization should be done on the basis of soil test information. In addition, most of the soils in the U.S. have been classified as to soil type. These soils are further classified as to crop yield capabilities so that producers have an estimate of potential forage yields from following the recommended soil fertility and management practices, e.g. Schmidt *et al.*, (1976). The USDA Soil Conservation Service also has classified soils as to the best land use from soil conservation standpoint and has provided farmers with cropping plans to best utilize their soils.

EFFECT OF CULTURAL PRACTICES AND RESEEDING

Early studies on methods of improving hill land pastures included cultural treatments such as disking and harrowing, plowing, and reseeding. In a Virginia study on bluegrass pasture, Carrier and Oakley (1914) found that disking or harrowing, or a combination of both, to reduce the so-called "sod-bound" condition or to improve the physical condition of the soil resulted in little or no effect over no treatment. They also found no advantage to alternate grazing over continuous grazing of bluegrass. Light grazing resulted in the deterioration of the pasture and the encroachment of weeds, and heavier grazing resulted in an improved turf and fewer weeds. Wiggans (1926) found that plowing and reseeding without fertilizing did not markedly improve the pasture, indicating that fertility rather than physical condition of the soil was the major pasture problem with unproductive weedy pastures. A combination of harrowing and reseeding gave similar results.

EARLY PASTURE RENOVATION STUDIES

Graber (1927, 1928) reported successfully establishing legumes in unproductive and unplowable bluegrass hill land pasture in Wisconsin by close grazing or burning, fertilizing, disking, and seeding. In a later publication, Graber (1936) outlined a program for renovating bluegrass pastures in which he emphasized the need for soil testing, liming and fertilizing, proper soil contact for the seed, and weakening and retarding the grass so that the seeded legumes have an opportunity to get established successfully (Table 7). Graber used alfalfa (*Medicago sativa* L.), sweet clover (*Melilotus alba* Desr. or *M. officinalis* L.), and red clover (*Trifolium pratense* L.) in his studies.

TABLE 7. Steps in renovating Kentucky bluegrass pastures (Graber, 1936)

1. Select field
2. Test soil
3. Lime and fertilize
4. Burn off old vegetation
5. Disk thoroughly
6. Level and smooth
7. Seed in early spring to drought tolerant legumes
8. Harrow or roll to cover seed
9. Regulate grazing

Other studies (Odland *et al.*, 1930; Borst and Yoder, 1943) confirmed the need for liming, fertilizing and some tillage for the establishment of the seeded grasses and legumes. Seeding failures were found to frequently result from inadequate suppression of the indigenous vegetation, showing the need for some effective method of controlling or eliminating the vegetative competition to the new seeding. Borst and Yoder (1943) showed that alfalfa could be successfully established on unproductive, eroded hill land in southeastern Ohio, primarily vegetated with broomsedge and povertygrass. Lime was applied, followed by disking in early spring to provide a trash mulch from the broomsedge vegetation as a protection against soil erosion. The seedbed was cultipacked following disking. Alfalfa-grass mixtures were seeded into the trash mulch with P and K fertilizer.

Concurrent studies in West Virginia (Smith *et al.*, 1944) also showed that legumes and grasses could be rapidly established in poor hill land pastures by using shallow tillage (disk, spring-tooth harrow or field cultivator), applying lime and fertilizer, and reseeding, without excessive runoff or erosion losses. Erosion was prevented by tearing up and destroying about three-quarters of the old sod and leaving a rough trashy seedbed.

During the 1940's and 1950's several studies in eastern U.S. on renovation of hill land pastures were conducted, confirming Graber's (1936) concepts of the need to soil test, lime, fertilize, weaken the existing vegetation, and introduce higher yielding species, thereby showing a marked increase in pasture productivity from renovation (Ahlgren *et al.*,

1944a, 1944b; Sprague *et al.*, 1947; Smith *et al.*, 1947; Midgley and Varney, 1953; Stuckey, 1952; Burger *et al.*, 1954; Brown *et al.*, 1960). Ahlgren *et al.* (1946a) increased the dry matter yield of bluegrass pastures over four times that of untreated pastures the first year after renovation. For the five years following renovation, the average increase in dry matter yield from renovation was over twice that of the untreated pastures. These researchers seeded red clover and biennial sweet clover into predominately Kentucky bluegrass sod. Wedin *et al.* (1967), introducing a perennial legume, birdsfoot trefoil (*Lotus corniculatus* L.), into a bluegrass pasture in the southern Iowa hill lands, not only increased beef cattle carrying capacity compared with unimproved bluegrass, but also increased the number of years that the improvement lasted (Table 8). The use of the legume also gave carrying capacity and beef gain per ha comparable to or better than bluegrass with nitrogen fertilizer. The animal average daily gains were higher on the trefoil-bluegrass pastures than on either fertilized or unimproved bluegrass.

TABLE 8. Carrying capacity of renovated and unimproved Kentucky bluegrass pastures (Wedin *et al.*, 1967)

Pasture Treatment	Grazing Days/ha Cow-calf 1956-57	Grazing Days/ha Yearling Steers 1958-63
Unimproved bluegrass	114	254
Bluegrass + N[1]	182	454
Renovated with birdsfoot trefoil	141	556

[1]67 kg N/ha annually.

Sprague *et al.* (1947) seeded both legumes (red clover, alfalfa, and ladino clover, *T. repens* L.) and grasses (orchardgrass, *Dactylis glomerata* L., smooth bromegrass, *Bromus inermis* Leyss., and timothy, *Phleum pratense* L.) into tilled sod. The use of the higher yielding grasses resulted not only in a marked increase in the initial dry matter yield of the pasture, but also in continuing improvement in yield compared with the predominately bluegrass sward used by Ahlgren *et al.* (1946a). Burger *et al.* (1954) also used higher yielding grasses and legumes in pasture renovation studies. Fall (early September) seedings resulted in better establishment than spring seedings (March).

Sprague *et al.* (1947) concluded that surface tillage was preferred to plowing because it left a surface mulch that prevented soil crusting from heavy rain, permitted more rapid infiltration of moisture and decreased runoff and soil erosion. With moderately fertile bluegrass sod, however, more horsepower was required to prepare a seedbed by disking than by plowing. The introduction of higher yielding grasses than bluegrass was another important improvement step in pasture renovation.

Stuckey (1952) listed seven basic principles for successful renovation of old pastures in Rhode Island: (1) avoid excessively droughty soils; (2) prepare a good seedbed, destroying as much as possible of the old sod or brush; (3) apply adequate lime; (4) use P and K annually; (5) seed an adapted forage mixture; (6) control intensity and duration of grazing; and (7) clip weeds.

GRAZING MANAGEMENT TO MAINTAIN IMPROVED PASTURES

Graber (1927) suggested that poor pasture production was often the result of overgrazing and that early close grazing of bluegrass should be avoided. He postulated that deferred grazing was necessary to allow vegetative growth of the plants to replenish food reserves in the storage organs if the pasture vigor and productivity were to be maintained. Severe overgrazing and no replenishment of soil nutrients resulted in heavy weed encroachment into bluegrass pastures (Fuelleman and Graber, 1938). They listed 47 weed species found in such weak unproductive pastures. Pasture renovation, including improved grazing management, markedly reduced the weed population. Burcalow *et al.* (1940) showed that without judicious grazing management, the duration and value of pasture improvement was greatly reduced. Moderate grazing of renovated pastures resulted in better legume persistence and fewer weeds than excessively grazed renovated pastures. Stuckey (1952) noted, however, that despite adequate fertilization and careful grazing management, pastures needed to be periodically renovated and reseeded regularly at 6- to 10-year intervals. Lassiter *et al.* (1956) showed no advantage of rotational grazing over continuous grazing with predominately bluegrass pastures.

PASTURE RENOVATION WITH HERBICIDES

Seeding failures from pasture renovation were frequently found to result from inadequate suppression of the indigenous vegetation. On sites too steep, erosive, stony, rough, or otherwise unsuitable for plowing, numerous diskings were often necessary to subdue the sod. The use of chemicals has aided greatly in controlling the old vegetation and reducing or eliminating the tillage needed for hill land pasture renovation.

Sprague (1952), in New Jersey, showed that chemical herbicides could be used to markedly reduce the competition to the new seeding from the existing sod and to the tillage needed in seedbed preparation as well. He reported that TCA (sodium trichloroacetate) killed old, well-established, and closely-grazed

Kentucky bluegrass. Orchardgrass and ladino clover were as successfully established in a seedbed prepared by two diskings of the chemically killed sod as in a seedbed prepared by 10–12 diskings or by plowing and four diskings. Virtually no bluegrass regrowth occurred in the chemically treated sod, but considerable bluegrass recovery was experienced in the pastures that were disked only. Kentucky bluegrass showed new rhizome growth within 30 days of application of sodium arsenite, despite immediate and good top kill. The thick vigorous bluegrass sod used in this study required some surface tillage in addition to the TCA treatment for successful seedling establishment and was considered more difficult to subdue in contrast to the thin weak sod on infertile soils used in earlier pasture renovation studies (Graber 1927, 1928; Borst and Yoder, 1943).

Further studies in New Jersey (Sprague *et al.*, 1962a) showed that other chemicals were effective herbicides for pasture renovation, but a difference in tolerance of the seedings to the various materials was found. This tolerance depended also on soil type, temperature, soil moisture, rate of application, and the length of time between herbicide application and seeding. TCA, amitrole (3-amino-1,2,4-triazole), cacodylic acid (dimethylarsinic acid), dalapon (sodium,2,2-dichloropropionic acid), E.H. 6249 (sodium 2,2,3-trichloropropionate), Erbon (2,-[2,4,5-trichlorophenoxy] -ethyl -2,2 -dichloropropionate), and 2,4-D were used at different rates, alone, and in combinations. Generally these herbicides were effective for pasture renovation and demonstrated the potential of this approach for suppression or eradication of old pasture sod. Considering labor and equipment costs of tillage, the use of several of the herbicides provided a pasture renovation technique cheaper in cost than the use of tillage alone. There also was some evidence of selective removal of undesirable grass species and broadleaf weeds from pasture sod. Cacodylic acid, for example, appeared to be useful for removing bluegrass and broadleaf weeds selectively while leaving orchardgrass. These studies also showed that legumes could be successfully drilled directly into pastures without tillage where the sod had been killed by herbicides. But as Sprague *et al.* (1962a) summarized, the use of herbicides merely removed the competition to the growth of new seedings, and reseeding, fertilizing, liming, and pasture management were still essential for successful pasture improvement. Sprague *et al.* (1962b) later reported a differential response of forage seedlings to the percent of sod killed by herbicides. Yield of sudangrass was markedly reduced when seeded in only partially killed sod as compared with largely killed sod.

Other studies reported during this period confirmed the New Jersey research. Harrington and Washko (1962) in Pennsylvania showed that birdsfoot trefoil, considered a more difficult legume to establish than alfalfa, red clover, or ladino clover, could be successfully established in a heavy Kentucky bluegrass sod sprayed with herbicides followed by disking. Herbicide applications in early spring (April and May) were more effective in suppression of the bluegrass than those made in midsummer or early fall (July through September). They reported that although the bluegrass may appear to be completely killed shortly after herbicide application, within 10 and 13 months there was a high degree of bluegrass recovery. Parsons and Davis (1964), in Ohio, also studied the use of herbicides for the establishment of birdsfoot trefoil into bluegrass pastures using dalapon and amitrole. With spring seedings, tillage was needed with spring-applied herbicides, but satisfactory stands were obtained with fall-applied herbicides without tillage. With the virtual elimination of the bluegrass, considerable encroachment of broadleaf weeds developed during the growing season, predominantly plantain (*Plantago lanceolata* L. and *P. rugelii* Decne.) and dandelion (*Taraxacum officinale* Weber). Triplett *et al.* (1975) noted a similar encroachment into herbicide-treated bluegrass. Wedin *et al.* (1967) also reported success in establishing birdsfoot trefoil into bluegrass pastures.

Fribourg (1962), in Tennessee, found that ladino clover could be successfully established in dense sod of tall fescue (*Festuca arundinacea* Schreb.) utilizing dalapon as a substitute for tillage. He reported that the herbicide rate could be adjusted to suppress only part of the tall fescue so that a satisfactory grass-legume mixture could be obtained. No clover establishment occurred in areas that were seeded but not sprayed with herbicide nor disked.

As pasture renovation techniques utilizing herbicides advanced, more sophisticated procedures were developed. Instead of broadcast spraying of the herbicide, Decker *et al.* (1969) in Maryland sprayed paraquat (1-1'-dimethyl-4,4'-bipyridinium salts) in a 15-cm band over the seeded rows of "Viking" birdsfoot trefoil and "Emerald" crownvetch (*Coronilla varia* L.) drilled into Kentucky bluegrass sod. Both legumes developed satisfactory stands, with the trefoil requiring several years to develop the desired stand. Band spraying reduced the amount of herbicide needed. Such a technique, by combining herbicide treatment, fertilizer application, and legume seeding with one machine, also provided pasture renovation with one trip over the field.

Taylor *et al.* (1969), in Kentucky, also applied paraquat in bands over the seeded rows using bands of 5.1 and 10.2 cm for establishing alfalfa and white clover into Kentucky bluegrass swards. They further used a specially developed tillage machine that tilled a narrow strip to a depth of 1.9 cm and several

widths (0.6, 1.9, and 5.7 cm). Paraquat banded over the seeded row improved legume stands only when the grass stands were dense and growth was vigorous. The use of tilled strips proved to be a successful technique for establishing the legumes. Shallow placement of the seed below the soil surface was found to be the most consistent factor contributing to successful establishment. Poorer stands were obtained in July and September than with March plantings, attributed to less favorable soil moisture conditions existing in mid and late summer. In a later study, Taylor *et al.* (1972), again using their special tillage machine, confirmed that legume stands were improved by placing the legume seed below the soil surface, regardless of date of planting, compared with seeds sown on the soil surface. Width of the tilled strip (0.6 or 5.7 cm) had no effect on stands or seedling size. Paraquat banded (10 cm) over the seeded row consistently enhanced seedling development in this study.

Van Keuren and Triplett (1970), in Ohio, using band spraying of paraquat (7.6 and 15.2 cm), successfully drilled alfalfa into four dense untilled grass sods (orchardgrass, bromegrass, timothy, and reed canarygrass, *Phalaris arundinacea* L.). Spring seedings were made with a grassland drill equipped with single disks followed by shoe-openers. The alfalfa was band seeded with P and K fertilizer. They further reported satisfactory establishment of alfalfa and birdsfoot trefoil into untilled bluegrass pasture with a combination of band seeding and band spraying of paraquat and dalapon. The alfalfa had good establishment the seeding year, while the trefoil required an additional year to develop a satisfactory stand. Seeding into the bluegrass with a standard grass drill either into sod broadcast-sprayed with dalapon or not sprayed gave unsatisfactory stands because of high variability of the legume stand.

Myers and Triplett (1974) outlined a 10-step pasture renovation program for Ohio hill land farmers involving paraquat, no-tillage, the use of a heavy drill to penetrate the sod and equipped with press wheels, and banding of the fertilizer with the seed. Statewide demonstrations in Ohio, using these 10 steps over a wide range of soil and climatic conditions, resulted in 80% of the seedings rated as successful (Myers *et al.*, 1974). Triplett *et al.* (1975) reviewed the role of herbicides in pasture renovation, including listing the characteristics of 15 herbicides used in renovation studies. Myers and Triplett (1974) emphasized the need to control pasture weeds prior to renovation and listed the use of 2,4-D as a standard practice. Strand (1976) showed the value to pasture improvement of controlling broadleaf weeds with 2,4-D ester and the importance of weed control as a first step in pasture improvement.

SOD-SEEDING EQUIPMENT

With the advent of limited tillage and no-tillage concepts in pasture renovation, it became necessary to develop seeding equipment capable of penetrating pasture sod and placing the seed in contact with the soil for best establishment. Hunt *et al.* (1963) reviewed the development of equipment for seeding forage crops. Band seeding was probably the most significant single development in which the legume or grass seed was placed in the soil and directly above, but not in contact with, drilled bands of fertilizer. Such a technique gave better stands and more vigorous seedlings than broadcast seeding, especially if the soil fertility was limiting. Heavy duty grassland drills capable of penetrating live or herbicide-killed sod were also developed, such as the commercially developed machine used by Van Keuren and Triplett (1970).

Decker *et al.* (1964) studied various soil openers for penetrating the sod and placing seed and fertilizer into the soil. They also showed that the use of press wheels following disk-type openers improved establishment, although not with a wing-type opener. Both the disk and wing openers were superior to the narrow opener following a straight colter found on conventional drills.

The Kentucky researchers took an original approach (Smith *et al.*, 1967) and developed sod-seeding tillage equipment with powered rotation disks to provide narrow tilled strips which precisely placed the seed at shallow depths and in direct contact with the soil. This was shown to be a superior method of establishing forages into pasture swards (Taylor *et al.*, 1969). This design has become a commercial production and is available on the market as the John Deere "Powr-Till." Another commercially available heavy-duty sod-seeder capable of penetrating pasture sod is the "Zip" seeder, used in the Ohio demonstrations (Myers *et al.*, 1974).

OVERSEEDING AND NATURAL RESEEDING

The natural reseeding of forage grasses (orchardgrass, Kentucky bluegrass, tall fescue, timothy, etc.) and of forage legumes (white and ladino clover, red clover, sweet clover, annual lespedezas [*Lespedeza* spp.], and birdsfoot trefoil) has been widely observed by forage researchers. It has also long been a practice of farmers in some areas to establish red clover and alfalfa in winter grain by broadcasting seed in late winter or early spring. Graber (1927) successfully established biennial sweet clover by overseeding at heavy rates (30 lb/acre, 34 kg/ha) on frozen bluegrass sod in Wisconsin during March and April, a period when alternate freezing and thawing of

the soil surface covered the seed sufficiently for establishment. Fuelleman and Graber (1938) found that, once established and with grazing management, this legume regularly reestablished itself by self-seeding. Brown (1944), in Missouri, showed that "Korean" and "common" annual lespedezas established relatively easily into perennial grasses without preparatory tillage, either by broadcast overseeding or by drilling. Lime and P were applied at or prior to seeding. Once established, the stands of lespedeza were renewed each year by natural reseeding. Fletchall and Brown (1959), in Missouri, reported that ladino clover established well in heavy stands of perennial grasses without tillage from spring seedings when followed by abundant, well-distributed rainfall. Tilling the sod invariably helped get stands of ladino clover, but it was essential only when planting was followed by dry soil conditions. Ladino clover overseeded in early spring in Missouri studies in tall fescue pastures not fertilized with N resulted in 11% legume on a dry matter basis, an amount sufficient to increase beef calf average daily gain and beef cow conception rates compared with tall fescue fertilized with N which had very little ladino clover establishment, Stricker *et al.* (1976).

In Kentucky Templeton *et al.* (1967) reported a significant increase in the birdsfoot trefoil stand in a Kentucky bluegrass pasture managed to permit natural reseeding to occur. A study in Ohio (Van Keuren, 1971) confirmed the Kentucky report and showed that the legume stand improvement was directly related to the amount of seed in the soil. This study also showed that sheep and cattle grazing trefoil with mature seed pods could distribute birdsfoot trefoil in the feces and thus aid in natural spreading of this legume. Taylor *et al.* (1972), in Kentucky, reported that with a doubling of the standard seeding rates, white clover and alfalfa were established by overseeding into undisturbed bluegrass sod in late winter or early spring prior to the end of soil freezing and thawing.

Maintenance of legume stands continues to be a major problem in forage management in the eastern hill lands. It appears that greater advantage could be taken of the self-seeding characteristics of legumes to improve and extend the longevity of legume stands in pastures. This would require forage management that included occasional delayed grazing for several months to allow seed to form. Following such a practice every several years might be adequate to build up the amount of legume seed in the soil. The practice of overseeding such legumes as red and ladino clover in early spring on closely grazed pastures, followed by grazing management to reduce the sward competition to the legume seedlings, also warrants further study.

UTILIZATION OF FORAGES IN THE HILL LANDS

Much of the feed for beef cows and sheep in the eastern hill lands of the U.S. is pasture in summer and hay in winter. This is in contrast to the heavy use of silage, haylage, and grain for dairy and fattening cattle. In recent years, there has been an interest in innovative systems of utilizing forages in winter feeding and in reducing labor requirement. Many beef cow-calf producers are former dairymen who have switched to beef because of the lack of labor or other reasons or are part-time farmers with full- or part-time off-farm jobs.

The use of field-stored hay as round bales and fall regrowth (all-season pasture system) for wintering beef cows has proven to be a practical method for areas with relatively open winters, such as in the hill lands of southern Ohio and Indiana, northern Missouri, West Virginia and Virginia (Hammes, 1975; Kaiser *et al.*, 1966; Peterson *et al.*, 1964; Van Keuren, 1970, 1972; Van Keuren and Parker, 1974). Tall fescue has been shown to be the best grass for this purpose, although the other commonly grown forage grasses are satisfactory. Tall fescue has been shown to persist and yield well under the close grazing and occasional sod damage by cattle treading that occurs during wet unfrozen periods in winter (Table 9).

TABLE 9. Yield of tall fescue[a] utilized in a winter forage system in southern Ohio, 8-year average, 1966–74

	T/A	% Crude Protein
Hay, one cut	2.3	9.4
Fall regrowth	2.0	10.8
Total yield, hay equiv.	4.3	

[a] 133 lb/A N annually in two applications.

The quality of the field-stored hay and regrowth of tall fescue has been shown to be adequate for wintering pregnant beef cows (Peterson and Garrigus, 1964; Van Keuren and Parker, 1974b). A major advantage of this system has been the savings in labor, equipment, and housing costs, reducing the labor required to about 25% of that for conventional drylot feeding of hay in winter (Van Keuren, 1972). A similar system has also proven practical for sheep, with some modifications (Thompson *et al.*, 1955; Parker and Van Keuren, 1970; Van Keuren and Parker, 1971, 1974a). With sheep, the ewes are moved to barn or drylot several weeks prior to lambing. After lambing, the ewes and lambs can be returned to the winter pasture again.

The earlier studies in the United States with field-stored hay for wintering beef cows and ewes involved using small, round, tied bales (40–60 lb, 18–28 kg) made with an Allis-Chalmers Rotobaler. Recently, a major development has occurred in hay handling involving equipment that makes large round bales (1 000–1 500 lb; 500–700 kg) and stacks (1–10 ton). These have been used for handling and storing hay for wintering both cattle (Van Keuren *et al.*, 1973; Smith *et al.*, 1974) and sheep (Van Keuren and Parker, 1973; Parker and Van Keuren, 1973). These large bales and stacks allow flexibility in the handling of winter feed. The hay has been fed in several ways: as bales or stacks left in the field, stored adjacent to the pasture and fed as needed by moving into the field, or fed in drylot. Feeding losses of small, round bales left in the field have been small (Van Keuren *et al.*, 1973), but the larger bales or stacks should generally be fed in limited quantities, in racks, or with accessibility to the hay controlled by an electric wire for best utilization (Lechtenberg *et al.*, 1974). Waste with hay stacks fed without a rack can be high (Renoll *et al.*, 1971). These recent developments in hay handling and storage are having a great impact on winter feeding of beef cow herds. The cost makes ownership of such equipment uneconomical for the producers of small herds, although custom hiring of such equipment is now being done.

ECONOMICS OF PASTURE RENOVATION

Cost studies have shown that commercial beef cow herds usually yield low returns. Shaudys and Sitterley (1963), in a study of beef production in hill lands of southeastern Ohio, found that about 15% of the producers studied had a profit above all costs. Almost all operators had a return above cash costs of operation. However, average return over cash costs was only about $519 per farm. Feed comprised 45 to 65% of the total production costs. The authors, as well as others recently have reviewed the literature and have cited other studies showing low returns. They have summarized some of the factors that influence returns from beef cow enterprises. Small herds are common. For example, in the hill lands of southeastern Ohio, the average size herd in a recent census was slightly over 18 cows (U.S. Department of Commerce, 1969). Calving percentages are frequently low. Often, large acreages are required per cow to provide feed For example, from 4 to 11 acres per cow (1.6–4.4 ha) are needed with unfertilized and unimproved pastures. Unpublished data from a current Ohio study (Van Keuren *et al.*) in the hill lands of Ohio showed 6.6 acres (2.7 ha) of unfertilized hill land pasture needed per cow. Blosser (1958), however, indicated that with top grade management, beef cattle could pay for a major forage improvement program in the hill lands of southeastern Ohio.

In an economic study of beef cow-calf feeding systems under southeastern Ohio conditions, White (M.S. thesis, 1969) showed that an all-season forage system, including field-stored hay and fall-saved regrowth for wintering, lowered the total cost per cow for all farm sizes compared with the conventional program including winter feeding of hay in drylot. Stock (M.S. thesis, 1972) showed a cost comparison for three cow-calf management programs based on Ohio data (Table 10). Extending the grazing season by the use of fall-saved pasture reduced the cost per cow over the conventional program used by producers. Use of all-season grazing with field-stored baled hay for winter reduced the cost still further. The studies by White and Stock were based on the use of nitrogen when fertilizer costs were less than they now are. The use of legumes to replace commercial nitrogen in the forage program should further reduce forage production costs.

TABLE 10. Cost comparison for three cow-calf management programs in Ohio (Stock, 1972)

	Per Cow Costs		
	Conventional	Extended Pasture	All-season Grazing
Feed	$47.00	$41.00	$31.00
Labor	30.00	15.00	10.00
Depreciation	10.00	10.00	10.00
Vet & medicine	3.00	3.00	3.00
Breeding charge	5.00	5.00	5.00
Building & equipment	6.48	4.08	3.08
Livestock int. 8%	16.00	16.00	16.00
Miscellaneous	2.50	2.50	2.50
	$119.98	$96.58	$80.58

LOOKING AHEAD

Currently, there is great interest in the interseeding of legumes into pastures and meadows to eliminate nitrogen fertilizer costs. The use of drought-tolerant legumes will give a better seasonal pattern of production, particularly during the occasional midsummer drought periods. The legumes also will improve overall forage quality, resulting in higher calf weaning weights.

Using legumes in the all-season grazing system will provide higher quality hay in the field-stored bales. Grass alone in the hay program is adequate for wintering pregnant beef cows and a spring-calving program. With legume-grass hay available, studies with fall calving were undertaken in Ohio so that lactating beef cows were consuming this higher quality feed during the winter (Parker and Van

Keuren, 1975). This proved to be a satisfactory program, and the calves were large enough to utilize spring pasture effectively. No winter creep-feeding of the calves was found to be necessary. An added advantage was found to be the improvement in reproduction efficiency and the high calving percentage of the cows (Parker *et al.*, 1976).

With the small round bales left in the field, only one crop of hay was harvested. With the large bales, it is easily possible to get several crops because the bales can be easily moved from the field or, in some instances, the second crop can be made around the first crop of bales. With legumes it is also more advantageous to make several crops of hay as is being done in current Ohio studies. At one location, three crops of hay are being made. This provides more of the winter feed as hay, by which the quality can be protected, and less as fall regrowth, which declines in quality during the winter. In a current Virginia study (Hammes, 1975), providing as much as possible of the winter feed for beef cows as autumn stockpiled tall fescue is being evaluated. Preliminary results indicate that under northern Virginia conditions, it may be possible to provide most or all of the winter feed from autumn stockpiled tall fescue growth.

The current development of herbicides is also providing new materials to use in pasture renovation. It is now possible to remove grass from legumes with pronamide (3, 5-dichloro [N'-1, 1-dimethyl-2-propynyl] benzamide). There is evidence of selectivity of herbicides to forage grasses, opening up the possibility of selectively removing some grasses from the sward, leaving others. An example would be to remove Kentucky bluegrass from an orchardgrass or tall fescue stand, or to remove tall fescue from orchardgrass.

The development of improved seeding equipment, such as the Kentucky strip-tillage concept, is another area that portends pasture renovation advances.

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DISCUSSION

Douglas Perry (West Virginia, USA). What's the maximum amount of legume you can carry in large bales through the winter?

Van Keuren. 100%.

Perry. You don't get any deterioration?

Van Keuren. There's a little bit more deterioration than there is with the grass alone but not markedly so.

J. E. Winch (Canada). You mentioned weeds and weed control—we find this is one of our main problems when we're trying to introduce trefoil into some of our rough land pastures. We have two types of weeds, the perennial types are there before you even start and after you clear up that vegetation you have annual and biennial weeds. My question is: What sort of a program do you suggest to farmers to control the weeds prior to and after the introduction of trefoil?

Van Keuren. The major serious weeds that we see in our pastures are Veronia, iron weed, and multiflora rose, and, occasionally, quackgrass and Canada thistle. We have to have a rather rigorous program ahead of time to attempt to eliminate these species. Frankly, I would say that we have not been entirely successful in controlling the major ones.

I'm not working with herbicides myself but we've instigated a program of 2, 4-D twice annually for several years on the Veronia, iron weed and the other pasture weeds, prior to renovation, and this seems to give us satisfactory control and we then go into a reseeding program.

R. Blaser (Virginia, USA). Concerning the renovation and establishment of legumes, I'm more and more of the impression that the cow ought to do all possible work in eliminating many weeds by close grazing. It's surprising how many weeds they'll eat, even thistles, so that we don't have to use Paraquat and costly means. I'm wondering whether they might not have literally been grazed into the ground, to a centimeter in height, and if this would not have eliminated the complications and made it possible to reestablish the legumes by throwing them on the soil. We maintained white clover that way in Virginia for 11 years and we have it in other pastures where it has been maintained for over 25 years without reseeding. So, I was wondering whether the chemicals and the complicated processes are necessary.

Van Keuren. I think we can go most of the way down the road to handling most of our weeds as you say. The ones that are difficult to control, such as Veronia, no respectable animal will eat.

Blaser. Can we get legumes established without having to use Paraquat?

Van Keuren. That's a question that is up for debate: Do we go the route of the herbicide, as many are doing, or do we have a simpler way of doing it? We might cite the work at Missouri where folks have simply overseeded Ladino clover into tall fescue. They have a tall fescue year-round program with cows and calves. They simply broadcast Ladino clover several years in a row in early spring. They have about 12 or 14% Ladino which is enough apparently to effectively influence the calf weight and the cow breeding performance. I think we also need to take advantage of the natural reseeding that some of the legumes do. I think folks in Kentucky have shown that we can do a nice job on maintaining trefoil if we just manage it so that it sets seeds periodically and perhaps, as Roy suggested, we can develop a procedure to do what occurs naturally. It's something we need to explore because these herbicides are expensive. Is there a cheaper way of doing it? I would like to go that route if we could find something.

14.
Factors Affecting Pasture Establishment in Noncultivated Seedbeds on Hill Country in Temperate and Sub-tropical Australia

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Australia is a large continent with a land area of 769 million hectares which is approximately the size of the United States. Although the contribution from secondary and tertiary industry to the nation's economy is rapidly increasing in significance, more than 50% of Australia's export income is still derived from rural (primary) industries (Fig. 1). Until the early 1970's animal production from grazed pastures was the most important component of the agricultural industries. Since then the cropping industries have increased substantially in importance. Over this latter period industries relying on production from grazed pastures have experienced very difficult economic circumstances because of a variety of factors, e.g. declining world markets for animal products and increasing costs for basic inputs such as fertilizer, seed, machinery and labor. A short-term contraction of the industries associated with grazed pastures has occurred. However, it is apparent that in the longer term to maintain Australia's prosperity and

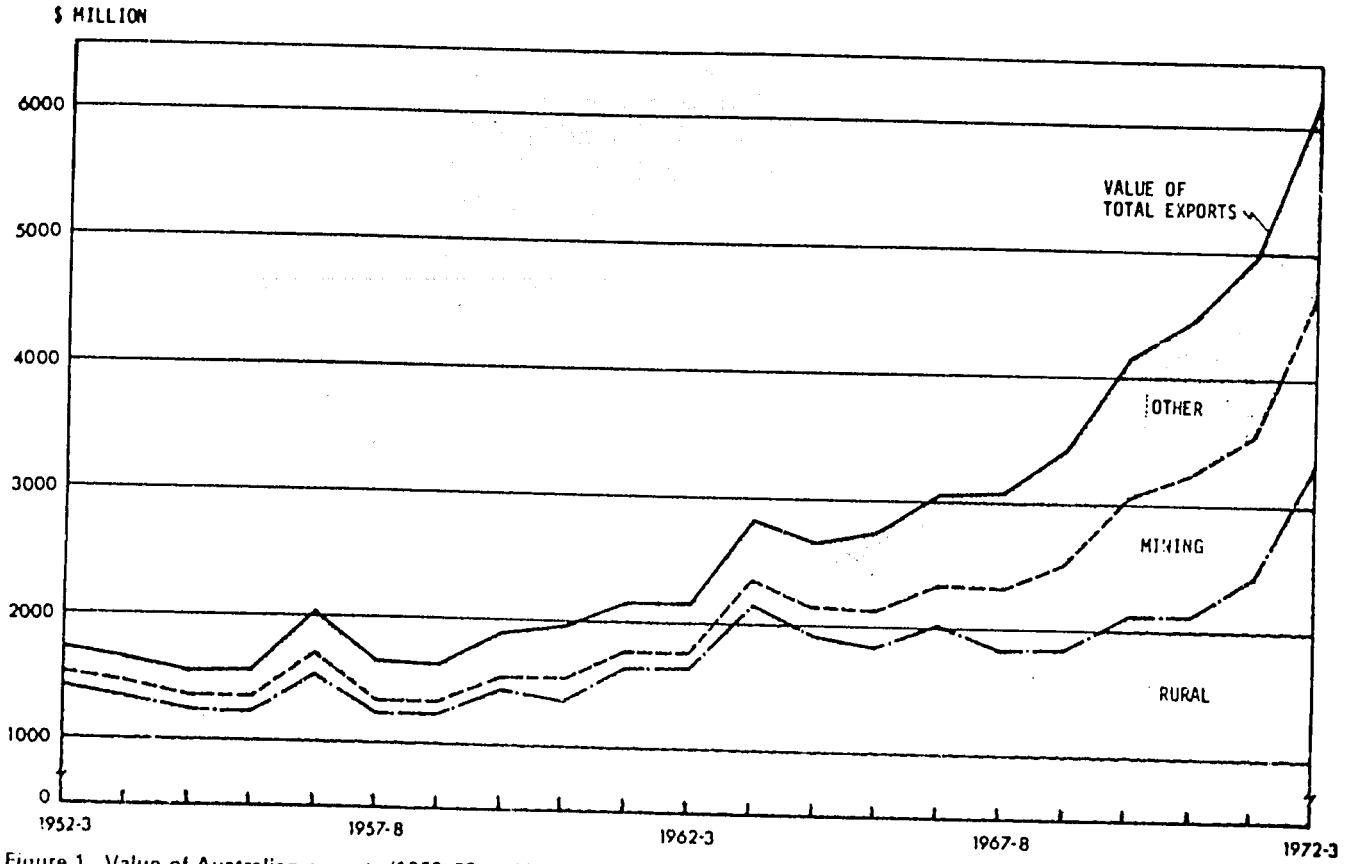

Figure 1. Value of Australian exports (1952-53 to 1972-73) (after *Rural Policy in Australia*).

to meet expanding world food needs, the grazing industries of the country must be maintained and developed as economically viable units. One way of doing this is through economic improvements in production per unit area in the extensive tracts of nonarable pastoral hill lands which exist throughout the continent. These provide an alternative location for grazing animal production as arable land is used increasingly for cropping. Use of more efficient and reliable noncultivated seedbed pasture establishment techniques in such areas is a basic prerequisite if the above objective is to be achieved.

Several contributed papers from Australian agriculturalists to this Symposium deal with recent developments in specific aspects of hill land improvement techniques (Hughes and Roberts—Tropical Eastern Australia; Dowling and Campbell—Temperate Eastern Australia; Adamson and Johnston—Mediterranean Eastern Australia). The purpose of this paper is to provide background and perspective to these specific papers by reviewing the major environmental, biological, mechanical and economic factors influencing the use of noncultivated seedbed establishment techniques for pastures on hill country in Australia as a whole. Progress made in developing reliable and efficient establishment techniques of this type is then reviewed and evaluated.

DEFINITIONS

One difficulty associated with reviewing literature relating to noncultivated seedbed establishment techniques is the confusion in terminology which exists when referring to particular establishment procedures. For the purposes of this paper, the various establishment techniques are divided into two broad categories:

1. Sod seeding, which is defined as drilling into an uncultivated sod by some mechanical means with or without the prior use of a herbicide. Some authors use the terms "direct-drilling" or "over-drilling" in this context, particularly if they wish to distinguish between sods treated with herbicide (direct-drilling) or untreated with such compounds (over-drilling). To simplify presentation the term sodseeding is used to include all such techniques.

2. Surface seeding, which is defined as the surface application of seed to uncultivated pasture areas with or without the prior use of herbicides. Frequently, the term "aerial seeding" is used in this context, however, the more general term "surface seeding" is used in order to be able to encompass techniques involving the use of aircraft plus other mechanical means of applying seed to the surface.

Brief reference also will be made to the relationship between sodseeding and surface seeding of pastures and "minimal tillage" of crops. Minimal tillage is defined as drilling of crops into areas which have received nil or a minimum amount of cultivation, with or without the use of herbicides.

POTENTIAL FOR PASTURE ESTABLISHMENT IN NONCULTIVATED SEEDBEDS IN AUSTRALIA

Advantages

The advantages of sodseeding and surface seeding for pasture establishment in Australia have been reviewed by Swain (1968, 1969a) and Campbell (1969a, 1969b and 1972). These advantages, in many respects, are similar to those for many other countries throughout the world. However, some have special relevance and significance to the Australian agricultural scene.

Almost all pastoral areas in Australia contain inferior unproductive pastures in their unimproved native state. Such pastures are, characteristically, perennial grass dominant, highly seasonal and low in quality. The lack of legumes is closely related to the almost universal phosphorous deficiency in the soils (Jackson, 1966). Development of viable, economic grazed pastures in these situations requires an initial input of improved species (especially self-regenerating legumes) and essential nutrients (particularly P). Annual legumes such as subterranean clover and townsville stylo have proved to be particularly important species in this situation.

Most farming enterprises are conducted on an extensive basis with individual owner-operator or company-owned properties occupying large holdings. In many situations pasture improvement is best achieved by the establishment of improved legume and grass species plus superphosphate fertilizer over as large an area on the property as possible in the shortest available time. Noncultivated seedbed establishment techniques are ideally suited for this type of development.

Support for such a strategy was given when policies for the rural sector were reviewed in 1974 (Anon., 1974). Extensive pastoral development was highlighted as one of three alternatives for the future. The other two choices were extensive dry land cropping and extensive pastoral development.

Sodseeding and surface seeding provide extremely effective means of achieving more efficient and extensive development of the pastoral industries, provided sufficient knowledge is available to ensure reliable plant establishment over the wide range of climatic and soil conditions which exist in Australia.

The Australian agricultural environment is extremely variable. It is frequently exposed to natural disasters such as drought, flood, bushfire, as well as widely varying seasonal conditions throughout the year. Under such circumstances, satisfactory pasture establishment techniques need to be available which provide the farm manager with the maximum flexibility to replace pastures, restore species balance, fill gaps in the feed year and/or to capitalize on particular climatic or market situations which develop at short notice. Sodseeding and surface seeding pasture establishment techniques have the potential to provide such flexibility. Accordingly, they can be extremely valuable tools for the farm manager in the whole farm situations.

LIMITATIONS

Area Available for Development. No precise figures are available on the potential area of land in Australia suitable only for sodseeding and/or surface seeding. Several publications contain figures on the total area potentially capable of supporting crops and improved pastures (Davies and Eyles, 1965); (Fitzpatrick and Nix, 1970); (Nix, 1975); and (Anon., 1974). These authors generally agree that inadequate rainfall is the key limitation to the area of agricultural production. Accordingly, nearly 75% of Australia is arid or semi-arid land unsuitable for crops or sown pastures (Fig. 2). It is also generally agreed that, in the areas potentially capable of supporting crops and pastures, a very large proportion of this land still awaits development (approximately 75%) (Davies and Eyles, 1965). Table 1 summarizes the present situation.

Let us now relate Davies and Eyles' (1965) figure, viz. that 150 million ha or 75% of the total area with sufficient rainfall for crops and pastures still awaits development, to the figures in Table 1 and Figure 2. This includes 35 million ha (23%) in the

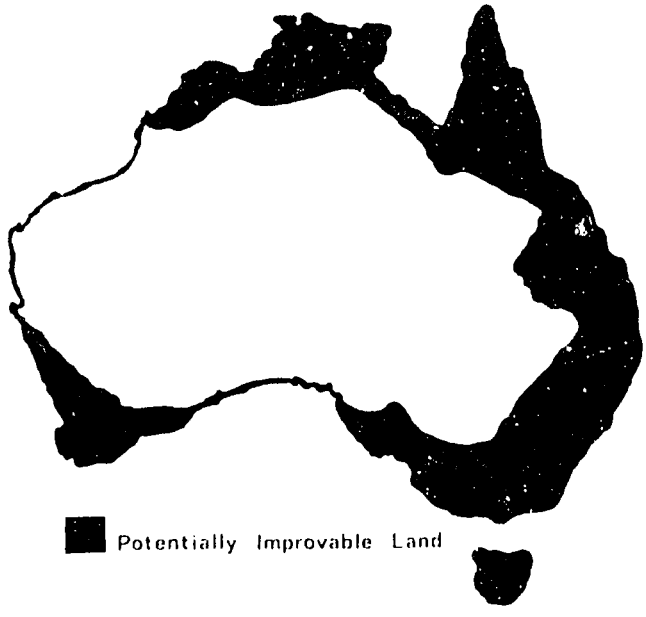

Figure 2. Potentially improvable land areas in Australia.

TABLE 1. Potential agricultural land in Australia with particular reference to nonarable land suitable for sodseeding and/or surface seeding

Type of Land	Hectare X 10^6	Percent of Total
1. Total area of Australia	769	100
2. Area of arid and semi-arid land	569	74
3. Total area with sufficient rainfall for crops and pastures	200	26
a. Area too rugged for agriculture	68	34
b. Area of shallow, stony or saline soils	55	28
c. Area suitable for rainfed agriculture and competitive uses	77	38

southern temperate and Mediterranean climatic zones and approximately 115 million ha (77%) in the northern subtropical and tropical zones. If it is assumed that a maximum of 62% of the 150 million ha of unimproved land in Australia is nonarable (see categories 3(a) and 3(b), Table 1) 93 million ha could only be developed if noncultivated seedbed establishment techniques were used. This is comprised of 22 million ha in the south and 71 million ha in the north.

In practical terms, the area of land which could be developed with noncultivated seedbed techniques would fall substantially below the maximum area of 93 million ha. However, even if it were only possible to develop 50% of the maximum (i.e., 47 million ha), it is apparent that an extremely large area of nonarable land remains to be developed (viz. 6% of the total land area of Australia). Such a program could only be justified and undertaken if reliable, efficient and effective noncultivated seedbed establishment techniques were readily available for the full spectrum of environmental situations which would be encountered. The above figures do not take into account that noncultivated seedbed establishment techniques also have an important role to play in the development of the 77 million ha of arable land in Australia (viz. 16% of land area of Australia) (Table 2, category 3 (c)). Hence, sodseeding and surface seeding of pasture species are very important and basic factors in the further development of Australia's agricultural industries, particularly nonarable land.

Environmental Biological Factors. The general features of the Australian environment have been reviewed by Fitzpatrick and Nix (1970), Mabutt and Sullivan (1970), Hubble (1970), Moore and Perry (1970), Frith (1970), Lovett (1972), Bruce-Smith (1972), McGarity (1972), and Lazenby and Swain (1972).

When related to the potential use of noncultivated seedbed establishment techniques, it is clear that the most important limiting environmental factors are precipitation, temperature, soil type and characteristics, inter-plant competition, and pests.

Lovett (1972) summarizes the situation with regard to precipitation and temperature (Fig. 3). He indicates that the tropical environments ". . . while enjoying relatively uniform temperatures throughout the year, suffer a severe winter drought which coincides with the most favourable incident radiation." The Mediterranean climatic areas contrast

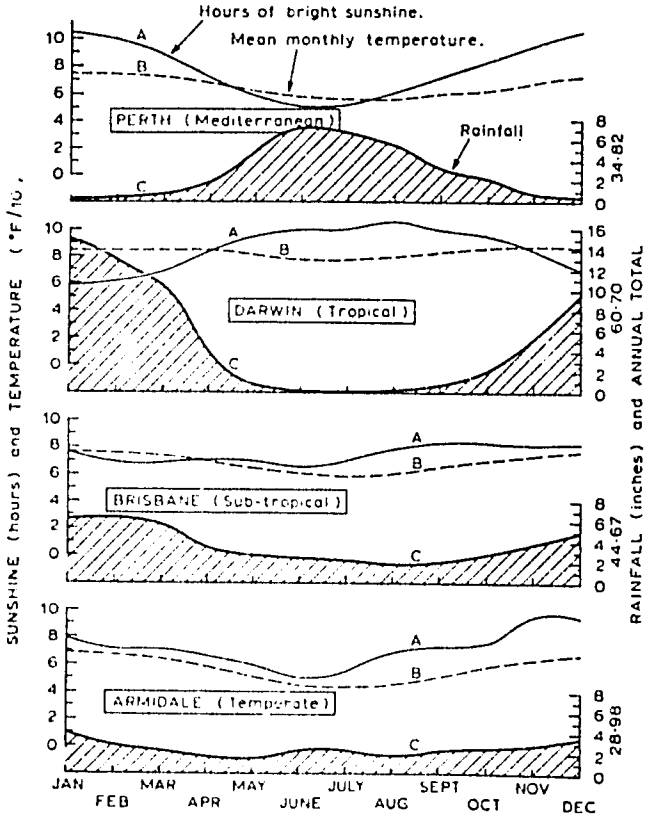

Figure 3. Examples of Australian climatic variation (after Lovett, 1972).

with this having ". . . considerably fewer winter sunshine hours . . . coupled with temperatures somewhat limiting to plant growth at the time when rainfall income is at its greatest." The subtropical and temperate climatic regions are more uniform in terms of annual rainfall distribution than either the tropical or Mediterranean zones. However, in the subtropical zone ". . . winter temperatures are limiting to the growth of tropical pasture species" and in the temperate regions ". . . the environmental limitations are mainly low temperatures in winter together with reduced solar radiation when rainfall is most effective."

Superimposed on the above situation is the fact that lack of reliability in rainfall pattern is a characteristic of virtually all of Australia. The only exception is the southwestern and southern areas of the Mediterranean climatic zone.

The majority of soil groups in Australia have equivalents in some other part of the world (Hubble, 1970); however, when considering their suitability for noncultivated seedbed establishment techniques, the following unusual features need to be taken into account:

1. The soils are almost universally of low nutrient status with widespread and severe deficiencies of phosphorus and nitrogen, and varying deficiencies of several trace elements.
2. Surface soils are of poor physical condition and, over large areas, are massive or weakly structured with low macroporosity, set hard on drying and tend to surface sealing.
3. Many areas contain soils which are very shallow, stony, saline or skeletal (having formed on porous sandstone plateaux). These soils are frequently associated with very rugged terrain where plant establishment can only be achieved by surface seeding with aircraft.
4. Most soils in Australia do not contain native strains of *Rhizobium* which will produce effective nitrogen-fixing nodules on sown legumes (Vincent, 1962, 1965; Norris, 1966). Accordingly, it is essential that sodsown or surface sown legumes are inoculated with the correct strain of effective *Rhizobium* and established in a manner which promotes effective legume-*Rhizobium* symbiosis. In particular, fertilizers harmful to *Rhizobium* and seed germination must be separated from sown seed.

Inter-plant competition is a seriously limiting factor when noncultivated seedbed establishment techniques are used (Campbell, 1968, 1969, 1972; McWilliam and Dowling, 1970; Swain, 1968). This applies whether sowings are made into existing native vegetation or improved pasture. However, the problem is particularly severe where soil fertility has risen significantly after a period of fertilizer use on sown improved pastures. Control of the existing vegetation, e.g. with herbicides or by mechanical means, is essential in almost every situation.

Pests, particularly ants, can reduce the establishment of surface sown seeds, especially if dry conditions follow sowing (Campbell, 1966; Campbell and Swain, 1973).

From this brief review of environmental limitations in noncultivated seedbeds it is apparent that very harsh and extremely variable conditions exist in most situations throughout Australia. Such a situation has resulted in sodseeding and surface seeding pasture establishment techniques gaining a reputation for unreliability. It has also resulted in an intensive and productive research effort aimed at quantifying and improving conditions for seed germination and seedling emergence and survival under sodseeding and surface seeding conditions. This is reviewed in more detail in the next section.

Mechanical Factors. Facilities for joint research, extension and teaching in agricultural engineering and agricultural science (i.e. the discipline of agricultural mechanization) are severely lacking in Australia. This was highlighted at the National Agricultural Machinery Workshop held at the University of New South Wales in 1969 (Swain, 1969b). In his report on the discussion, as chairman of the Workshop, Swain stated that "there is a general lack of communication between the engineers and the agriculturalists with the result that the limited development of new agricultural machinery in Australia is often carried out without the needs of both these disciplines being defined and taken into account." He listed specific examples where improvement in the precision and versatility of machines was needed. Two of the five examples listed related to sodseeding and surface seeding:

> ". . . (III) (a need for) all-purpose minimum tillage equipment. In particular, it was agreed that there was a serious deficiency in sodseeding equipment; . . .
> . . . (V) the development of more effective and precise means of sowing seed and fertilizer from aeroplanes."

The above situation has hampered the development of sodseeding and surface seeding machinery designed specifically to meet the special needs and limitations of the Australian environment. However, the National Workshop in 1969 has helped stimulate research activity in these areas and the results of this activity will be discussed in the next section.

Economic Factors. The Australian producer, extension officer and research worker concerned with sodseeding and surface seeding are constantly faced with a dilemma. On the one hand, as stressed earlier, there are huge tracts of land urgently requiring pasture improvement. Sodseeding and/or surface seeding provide the fastest and often the most feasible establishment techniques for achieving such development. On the other hand, current sodseeding and surface seeding technology is such that the establishment of pastures using these techniques is frequently unreliable and often leads to very costly failures. There are inadequate guidelines to enable a sound choice to be made between the following alternatives:

1. Situations when and where sodseeding and surface seeding can be used over large proportions of an individual property with a high prediction of success; or
2. Situations where pasture improvement should be confined to arable areas of the property, using conventional, cultivated seedbed establishment

techniques, because risks are too great to develop the nonarable areas.

In (1) the producer can anticipate a significant increase in total property production at low cost; but with lower production per unit area from the improved area compared with improved areas in alternative two.

In alternative (2), production per unit area on improved arable land will be high, as will be costs, relative to (1). Increases in total property production will vary according to the area of arable land available.

Very few Australian studies integrating the biological, engineering and economic aspects of noncultivated seedbed establishment techniques have been undertaken (Swain, 1968 and 1969a). However, a start has been made. Hutchings (1967) studied the cost and efficiency of various sowing strategies. Collins *et al.* (1969) reported benefit/cost relationships in pasture and crop establishment. Hudson *et al.* (1965), Colman *et al.* (1967) and Swain *et al.* (1970) reported on the physical and economic evaluation of sodseeded pastures in whole farm systems in subtropical NSW. Crofts (1963) has undertaken similar studies in the County of Cumberland, NSW. Dowling (1976) has reported on an economic evaluation of surface sown pastures in progress in the hill country of northern NSW.

RECENT DEVELOPMENTS IN PASTURE ESTABLISHMENT IN NONCULTIVATED SEED BEDS IN AUSTRALIA

Sodseeding

The first specially designed commercial sodseeder in Australia was based on the work of Breakwell and Jenkins (1953). The machine was very simple in design consisting of standard 3-point linkage seed and fertilizer boxes plus tiller with a specially designed shoe or opener. The opener made a relatively wide cut (5 cm) in the sward. Reliable establishment of large and medium-sized species was achieved but many failures occurred with small-seeded species such as white clover. Seed and fertilizer were not separated in the row.

The machine described was the basic unit for most sodseeding work undertaken during the 1950's and early 1960's. Serious limitations were found and reviewed by Swain (1968 and 1969a); Campbell (1969a, 1969b and 1972a); Carter and Saunder (1969); and Stonebridge and Mackie (1969).

In summary, major problems were encountered in two broadly differing situations.

1. In the more intensive farming situations, plant establishment was patchy and unreliable. This was due mainly to a lack of precision in the location and placement depth of the seed and fertilizer. For example, few conventional drills displayed sufficient vertical coulter movement to accommodate ground contour changes. This resulted, in some cases, in seeds not being buried adequately and losses occurring from ants, birds, rodents, unsatisfactory moisture conditions for germination and emergence, desiccation of the emerging radicle and shoot, and inadequate anchorage for seedling roots (Carter and Saunders, 1969). In other cases, seeds were buried too deeply and were unable to emerge, and/or the groove in the sod closed over before emergence took place. Such problems were frequently coupled with severe competition from the existing sod in the early development stages of the seedling.

2. In very rugged, stony terrain the existing machines lacked maneuverability and frequently could not withstand the damage caused by such conditions. Accordingly, one of the major advantages of the sodseeder was lost because a significant proportion of the huge tracts of nonarable land in Australia could not be developed with the sodseeder. Hutchings (1967) provided an excellent summation of the situation at that time when he stated that it was both possible and desirable to effect substantial improvement in the efficiency of perennial pasture establishment in southeastern Australia through the use of such strategies as the use of herbicides and sodseeding and the improvement of the precision of sowing equipment. He saw the latter factor as a challenge to manufacturers of farm machinery.

Campbell (1972) reported that progress had been made in overcoming some of the above problems by the development of attachments which made a wider cut in the sod (Swain and Seccombe, 1969), by machines which gave better cover to the seed in the rows, and by herbicides (Murtagh, 1963; Cocks, 1965).

Sodseeders incorporating a disc coulter assembly intended specifically for direct drilling were imported from New Zealand in an attempt to overcome, in particular, the problems encountered in the intensive farming situation described in (1) above. The New Zealand machines were based on work undertaken in the United Kingdom (Karonka, 1973).

However, up until the late 1960's, limited progress was made in improving and extending the range of uses for the sodseeder in Australia. Since then a comprehensive series of studies has commenced in both Australia and New Zealand where both the biological and engineering problems of sodseeding have been studied in an integrated manner. In Australia, this work is being undertaken by the CSIRO, Division of Plant Industry in conjunction with the University of NSW (Hutchings, private communication). In New Zealand, similar work has been undertaken by the Department of Agronomy, Massey University (Baker, 1976).

In Australia, the work has resulted in the develop-

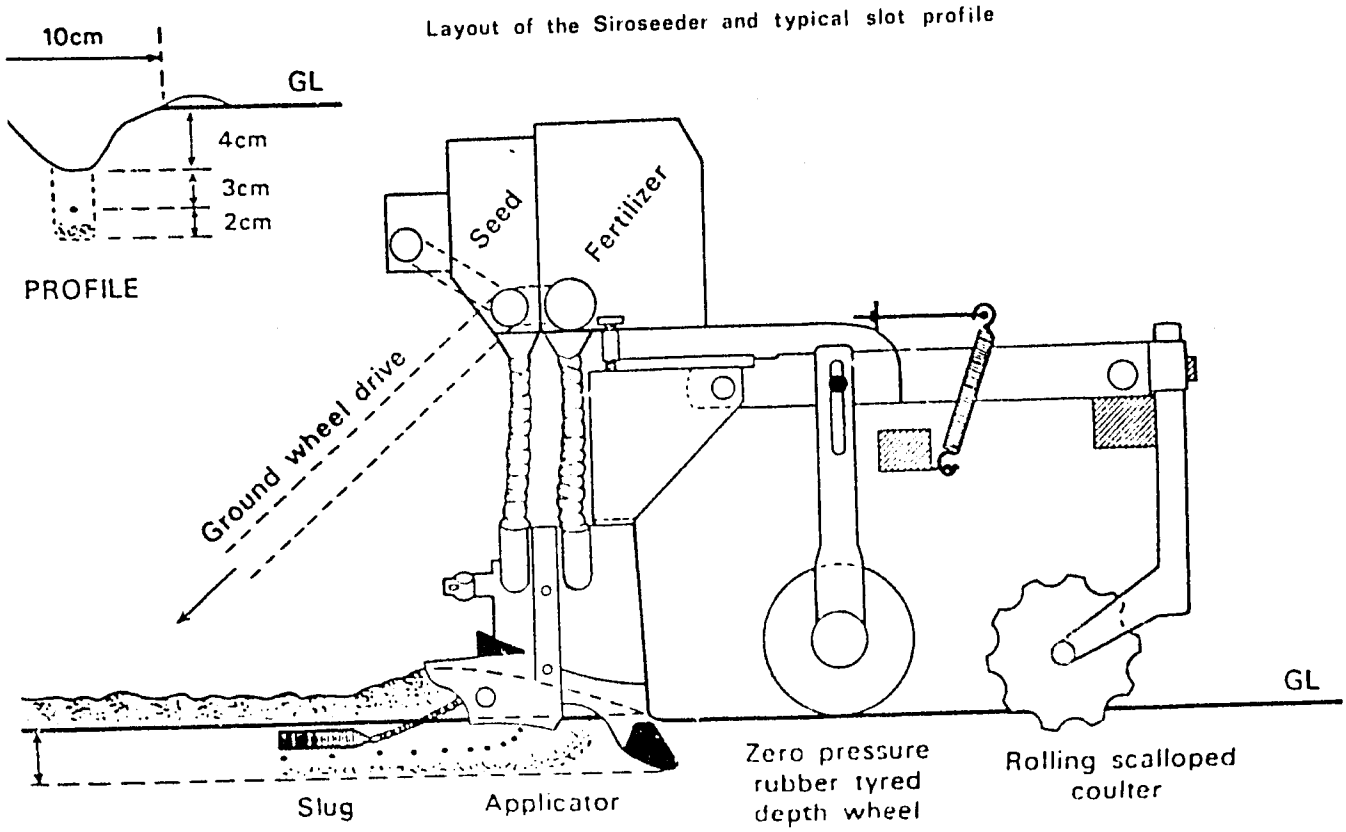

Figure 4. Siroseeder and typical slot profile.

ment of a precision sodseeder called the Siroseeder, Fig. 4, for intensive farming situations described in (1) above. The development of the Siroseeder paralleled that of the five-disc or Unirow sodseeder, derived jointly with the University of NSW. At the same time, work commenced on a Divot seeder which was devised for low cost development of unimproved, rough, eroded and rugged terrain situations described in (2) above (Hutchings *et al.*, 1972a and 1972b) and (Anon., 1976). Plants are sown in a micro-seedbed in individual divots removed from the existing sod on a 46 cm grid.

The objectives of the recent sodseeder work referred to above have been summarized by Sweeting (1974). The essential features of the five-disc sodseeder are described below and are illustrated in Figs. 4 and 5.

Each individual seeder has five discs. Twin opposed discs, one behind the other, open the sod throwing a 10-cm slice in either direction and at the same time inverting it on the adjacent sward. The rear assembly comprises three discs set one behind the other. The first is angled in the opposite direction to the two following and is for fertilizer placement. The second disc cuts a furrow for the seed and the third is the coverer. All three discs thus work in clean ground and the rear press wheel compresses the ground.

The operation principles incorporated in both the Siroseeder and the five-disc sodseeder represent modifications and refinements of the principles incorporated in the sodseeder openers described by Swain (1961) and Decker *et al.* (1964).

The work undertaken by Baker (1976) in New Zealand set out to answer the following questions: What soil physical conditions best suit seeds sown into untilled seedbeds? What mechanical designs of seed drill coulters and ancillary equipment best fulfil these demands?

It is not within the scope of this paper to report in detail Baker's work; however, brief reference is made to his main findings because of their relevance and complementarity to present-day Australian work with sodseeders.

In his PhD thesis, Baker reports on the successful development of experimental equipment to permit a close study of the biological and physical (mechanical) factors influencing the early establishment of seed sodseeded into sprayed pastures. This equipment is unique, to the best of the writer's knowledge, and provides an extremely effective means of undertaking detailed and precise studies to answer the

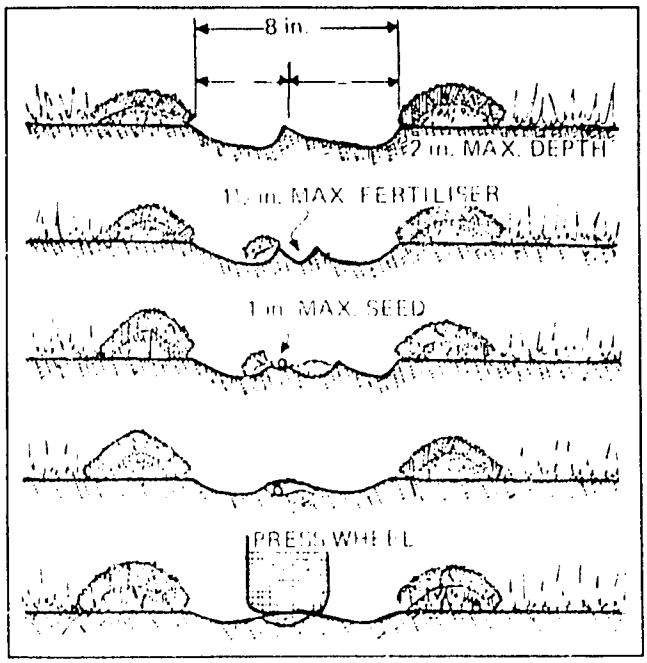

Figure 5. Sequence of operation of five-disc sodseeder (after Sweeting, 1974). Top to bottom: opposed overlapping furrows opened by front discs; furrow for fertilizer opened by leading disc in three-disc rear assembly; fertilizer covered by center disc which also opens furrow for seed placement; rear disc covers seed; and finally, presswheel firms seed.

two questions posed above by Baker.

Baker also outlines a series of experiments aimed at determining the importance of various factors present in the environment within or immediately adjacant to the groove produced by sodseeder machinery. In addition, he reports on the development of a radically different chisel sodseeder. Improvements were recorded for seedling emergence and operational force requirements when using such a drill in comparison with hoe and triple-disc coulters.

Recent Australian and New Zealand research on the development of sodseeders which are more effective over a wider range of conditions is still in a preliminary stage. However, it is apparent that real progress has been made, particularly where the efforts of the agriculturalists and the engineers have been combined. The time is now most opportune for some collaborative work between Australian and New Zealand workers. For example, the characteristics and effectiveness of the newly developed Australian sodseeders, such as the Siroseeder, the five-disc sodseeder and the Divot seeder, could be more clearly defined if they were studied using the new experimental equipment developed by Baker in New Zealand and referred to above. It is also apparent that the new sodseeders have potential as multi-purpose units, useful for both the establishment of pastures and in the minimum tillage establishment of crops (Hutchings, 1974; Hutchings and Hicks, 1975; and Anon., 1976.)

SURFACE SEEDING

The history (up to the late 1960's) and fate of surface seeding as a means of pasture establishment in Australia, has been extensively reviewed and summarized by Newman (1966); McDonald (1968); Swain (1968 and 1969a); Campbell (1969b and 1972a) and McWilliam (1969).

McWilliam (1969) provided a concise statement of the situation at that time, when he indicated that "there is no doubt that aerial (surface seeding) is a valuable new tool in the hands of the agriculturalists, and one that is well suited to the type of extensive pasture development that is needed in many parts of Australia. Despite the numerous technical and economic problems that are curtailing its more widespread application at the present time, there is every indication that it has an important future."

The foregoing statement was made at the first National Agricultural Machinery Workshop held in Australia. The workshop marked a turning point in the development of surface seeding as a pasture establishment technique in Australia. There was general recognition that the "hit-or-miss" attitude to surface seeding could no longer be justified, particularly because of the increasingly difficult economic circumstances being encountered by rural producers. Major problem areas associated with the unreliability of the technique were identified at this workshop and related conferences held at the same time and research in the 1970's has been directed at overcoming these limitations.

The major problems were classified into biological and technological categories. Biological problems included:

1. The definition of factors limiting successful establishment of pastures from the air;
2. a means of controlling competing vegetation;
3. an understanding of the optimal time for sowing;
4. determination of the most desirable treatment of the seed and of the site (e.g., cover) to provide the best conditions for establishment;
5. breeding and selection of species adapted to surface seeding; and
6. control of pests removing seed prior to germination.

The major technological problems listed were

1. A need for more effective and accurate placement of fertilizer and seed from aircraft (e.g., granulated fertilizers, pelleted seed and improved delivery equipment); and
2. recognition, development and communication of the special skills required by aircraft operators

to overcome the problems and variables encountered in various environments when undertaking surface seeding operations.

Since 1970, considerable progress has been made in overcoming many of the problems listed above, particularly those in the biological category. The current recession in the rural industries has been particularly severe in the aerial agriculture sector and has precluded any major effort in the technological area. The lack of agricultural mechanization research facilities in Australia, referred to earlier, has also contributed to this latter situation.

McWilliam and Dowling (1970), McWilliam *et al.* (1970) and Dowling *et al.* (1971) have contributed significantly to our knowledge on the biological problems (1), (2) and (3) listed above through their work in the laboratory and the field. This showed that the water relations of the micro-environment surrounding the seed are of major importance and that plant species vary significantly in their reaction to such conditions.

Campbell (1972b) and Campbell and Swain (1973a and 1973b) reported on a major study of the biological problems listed in (1) to (4). The overall objective was to define the factors responsible for losses during germination, radicle entry, establishment and survival of surface-sown pasture species. A "balance-sheet" approach studying individual seeds was adopted as a means of rating the factors responsible for losses in order of importance. Principles involved in radicle entry were defined as a prelude to related field trials by glasshouse experiments. The separate and combined effects of strength, tilth and heterogeneity of the soil surface on the radicle entry of four pasture species were studied. The studies revealed that marked heterogeneity on the soil surface helped offset the effect of soil strength and permitted rapid radicle entry. Smooth uniform soil surfaces caused slower radicle entry, particularly if soil strength was high and thus the radicles suffered from a longer period of exposure to desiccation. The radicle entry ability of the four species declined in the order: perennial ryegrass < phalaris < lucerne and subterranean clover.

Related field studies provided detailed, quantitative information on the "balance sheet" of the fate of surface-sown seeds. Major losses during establishment were due to ant theft of seed; poor germination; desiccation of the radicle tip; competition from weeds; and moisture stress. Dead plant cover on the soil surface and winter sowing reduced losses. However, the adverse effects of severe moisture stress on the survival of young plants frequently overrode all other factors.

The next phase in the development of reliable and efficient surface seeding techniques for pastures in Australia is to translate and relate the various principles, which have been enunciated in recent years, to the various regional environments which exist throughout Australia. The two papers contributed to this Symposium by Campbell and Dowling provide an excellent demonstration of this latter type of approach. An essential followup to such work will be the close collaboration of research agronomists and farm management personnel with the extension worker and the producer. Their task will be to interpret the findings for the individual farm situation. Guidelines on the factors which must be accounted for before surface seeding techniques are used must be clearly laid down for individual property situations. The level of risk involved must be quantified and related to possible alternatives (if any exist).

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DISCUSSION

J. Washko (Pennsylvania, USA). One of the factors that we have alluded to is that this is an expensive process no matter which way you go about it because of seed costs, fertilizers, etc. One of the things that

prospective users of reseeding techniques are interested in is how long their legume stand will last. How long have you been able to keep some of these legumes in after you have renovated? We've got to think not in terms of the initial cost but the amortization over a period of years.

Swain. I agree with you; this is certainly a very important issue. I think my comments would be a little different as far as sod-seeding is concerned, compared to aerial-sowing. Take the aerial- or surface-seeding first: given that you maintain the correct fertilizer applications, particularly the phosphate and molybdenum, then with reasonable management it is usually possible to maintain the legumes for many years, subterranean clover particularly, but even alfalfa as well. The biggest problems occur when there's a relaxation of the fertilization program, particularly for phosphate; then the legumes quickly disappear from the pasture. The other problem that can occur is legume loss due to one of the more serious droughts. For example, during the 1960's we had a whole series of bad droughts throughout the country and in many cases we lost the legume stands. But, generally, the areas that we would be developing with aerial-seeding, particularly the temperate area, are reasonably stable once you get successful establishment. (I think Dick Roberts can comment more on the subtropical situation.) As for sod-seeding, frequently the seeder is unreliable for perennial legumes; or even where legume establishment is successful, it fails to survive because you change the system so much by increasing the fertility of the grass and so on. Thus the sod-seeder has been seen more as a short-term flexible tool that you use to restore the balance either with a legume or a grass (generally annuals). One hopes that with the development of precision implements, such as those in this paper, you can get the perennial species in there and keep them there. But longevity is a bigger problem in the areas where we're more likely to sod-seed than in the surface-seeding areas.

T. Taylor (Kentucky, USA). My comment is more on the seeding that you did there and pegging down the seed. Covering the seed, as indicated earlier, will result in larger plants earlier. Now, we have alfalfa and white clover. We put the seed on top of the ground and we cut it into the ground and we get larger plants and more plants per 100-seed planting. I think this covering does help and trampling the seed will help—that will cover the seed.

Swain. Yes, I would agree and I know that Peter Dowling will want to comment on this in the paper that he gives. Provided that this cover is not competitive it can be a very valuable asset. There are some reasonably complex interactions between the cover and the soil surface and the moisture/temperature relationships. We see controlled use of cover as one of the ways we can directly improve the reliability of surface-seeding. We would like to be able to use stock for trampling in pastures and we have shown the merit of that in situations where stocking rates are relatively high.

G. Jung (Pennsylvania, USA). I read in a paper published in Australia that ryegrass has a tolerance to moisture stress under conditions of establishment that put it in a class all by itself. Other grasses and legumes that were placed under a moisture stress caused stand failures as the moisture stress was increased and at a point in which there was almost total failure of these other species, ryegrass was giving a stand of 60%. This then would suggest that under sod-seeding conditions, our chances for success with ryegrass would, under many of our conditions in the U.S., be far better than they would be with some other species.

Swain. Yes, I think you're referring to the work that Malcolm Campbell and I did at the University of New England, and certainly in greenhouse conditions that we worked in we were able to demonstrate just what you said. As far as early establishment in the field was concerned, the same response was found—that ryegrass has an adaptability to surface-seeding, and I guess sod-seeding as well, that would tend to put it in another category. It certainly, as far as radicle entry, is by far the best method—it just plugs the radicle straight in. We found that some of the other species could perform more like ryegrass if we took full advantage of the cover situation mentioned in the previous question. But ryegrass still stood out. The overriding problem is that frequently the survival of species, once you've got a successful establishment, will be the major factor. If you get hit with a big drought, say in the second year, or some very adverse management conditions associated with dry weather, the ryegrass is no better able to handle than the other species we were working with. But at the early establishment phase, particularly as far as surface-seeding is concerned, there appear to be real benefits with ryegrass for future breeding and selection work to develop more reliable species for sod-seeding and surface-seeding.

15.
Legume Based Pastures on Tropical Hill Lands

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In most tropical countries the lowlands are intensively cultivated, but much of the hill land is comparatively undeveloped.

This is largely true even in densely populated areas like southern China where, despite some spectacular terracing for cropping and extensive reforestation programs, there are still large areas of mountainous country which are relatively unproductive.

If these lands are to be more fully utilized, there would appear to be two main alternatives—forestry or grazing. The relative merits of each will differ from one country to another but as population pressures increase the utilization of hill lands for grazing will become increasingly important.

Animal production from natural pastures in the tropics generally is much lower than would be expected in temperate zones of similar rainfall. This is mainly due to the poor quality of tropical grasses, compared with temperate grasses, which prevents animals from fully utilizing the very large quantities of dry matter produced. This is aggravated by a general lack of native pasture legumes.

In the past 15 years or so many improved tropical pasture grasses and legumes have become available and productive pastures can now be established practically anywhere between latitudes 30° N. and 30° S. where rainfall is of the order of 700 mm or more and is fairly well distributed and/or reliable.

LIMITATIONS OF SLOPE

Many tropical grasses form open swards, with bare ground exposed between tufts even in areas of high rainfall. Consequently the danger of erosion on steep slopes is great, especially if overgrazed.

Probably because of this, a report to the governments of Malaysia and the State of Johor (Hunting Technical Services Ltd. *et al.*, 1971), recommended that grasses be confined to slopes of 0–12°. This slope classification also included crops which are normally clean cultivated, such as bananas, sugar cane, pineapples and coffee. Tree crops frequently grown with a ground cover crop, such as oil palm, coconut, rubber and tea, were recommended for slopes up to 20°, and forest under controlled exploitation to 25°. These recommendations limit pasture development to the lower slopes, but these areas can be more profitably used for agriculture or horticulture, and this paper is mainly concerned with the development of pastures on land which is classified in the above report as rolling to steep (6–25° slope). The Johor Tengah Region of Malaysia has a total area of 131 396 ha, of which 43 212 ha is classified as rolling (6–12°), 14 085 ha as hilly (12–20°) and 19 512 ha as steep (20–25°). Thus, if the hilly and steep lands could be safely developed, the area available for animal production in this region would be almost doubled.

Properly managed tropical grass-legume pastures are less subject to erosion than native grasslands because the bare patches between the tufts of grass can be filled in with legumes. Consequently a complete ground cover can be maintained, provided the pasture is adequately fertilized and not overgrazed. It is considered that under these conditions slopes of the order of 20° to 25° may safely be developed for grazing if reasonable precautions are taken to minimize erosion during the establishment phase.

In northern New South Wales abandoned banana plantations on slopes of up to 35° have been successfully sown to tropical grass-legume mixtures (C. R. Roberts, unpublished). Judging by the degree of siltation in dams at the foot of these slopes, erosion is now negligible and certainly far less than it was under the previous cover of weeds, naturalized grasses and scattered shrubs. Judging by the improvement in soil color and texture since the pastures were established there has been a net gain in fertility and minimal loss of soil by erosion.

ACHIEVING A NEW ECOLOGICAL BALANCE

Before embarking on any program of pasture development it should be clearly understood that some change in the environment will have to be made if the introduced pasture species are to form a stable and productive association.

It is not sufficient simply to sow seed of improved pasture species and expect to obtain higher production. It must be remembered that the existing species are there because they are well adapted to the existing environment and it is unlikely that introduced species will be able to compete against the indigenous vegetation, particularly when they are subjected to (preferential) defoliation by grazing animals, unless the environment can be altered in some way to give the introduced plants a competitive advantage.

Simply removing the existing vegetation by clearing or plowing will often be sufficient to enable the new species to become established, but they will seldom be productive and persistent unless soil

fertility can be improved. This is particularly true of hill soils which are usually of lower fertility than alluvial soils derived from the same parent materials.

Nitrogen and phosphorus are commonly deficient on hill soils, especially when these lands have been previously cultivated. Pure grass pastures must be supplied with both N and P, but an effectively nodulated pasture legume is capable of fixing appreciable quantities of N, provided it is well supplied with P and all other essential nutrients from the soil or fertilizer. N additions can be detrimental to legumes and should only be used in special circumstances (Jones, 1970).

There is thus a choice between grass-legume pastures fertilized with P, or pure grass pastures fertilized with N and P—plus other elements as required. The grass + legume system will produce animal products at lower cost than grass + N. For example, in Malaysia it was estimated in 1975 that the cost of fertilizer per kg. of dry matter from Napier grass (*Pennisetum purpureum*) pastures fertilized with N was from two to four times higher than the fertilizer cost of producing dry matter of at least equal, and usually better, feeding value from mixed pastures of Guinea grass (*Panicum maximum*) and stylo (*Stylosanthes guyanensis*) (Roberts, 1975). Labor costs would also be higher on the intensive pure grass system. On the other hand, grass-legume mixtures are essentially an extensive system, requiring approximately twice as much area per animal as heavily fertilized grass pastures (Jones, 1974a). Vicente-Chandler *et al.* (1974) also quoted carrying capacities for grass pastures about twice as high as I have suggested for legume-based pastures.

Grass-legume pastures are therefore to be preferred in all cases where availability of land is not a limiting factor, as they offer the best possibility of producing much needed animal protein in tropical countries at a price which the people can afford. In most tropical countries the total area of under-utilized hill land which could be used for this purpose is quite large.

There are, however, some situations where land is at a premium and a market exists for high priced animal products, for example in Hong Kong, where the intensive, high cost, grass + N system is economically justified. There is also a good case for incorporating areas of pure grass pasture into a grazing system based mainly on grass-legume mixtures for management purposes, as will be discussed later.

SEED BED PREPARATION

No Soil Disturbance

Dense rainforest can be cleared by traditional slash-and-burn techniques and tropical grass-legume mixtures successfully established by sowing into the ash. Unburnt timber should be stacked against stumps for later burning, otherwise cattle may be trapped among fallen trees and mustering will be difficult.

On lightly wooded or previously cleared slopes it is sometimes possible to establish grasses and legumes without cultivation. Burning and sowing into the ash as soon as it is cool is the method most likely to succeed. As competition from existing species is only temporarily checked, establishment will be slow and grazing will have to be carefully controlled for some years until the old vegetation has been eliminated.

In Fiji, Partridge (1975) has established siratro (*M. atropurpureum*) in mission grass (*Pennisetum polystachyon*) by broadcasting seed and superphosphate after mowing the grass. In Uganda, T. H. Stobbs (personal communication) established stylo by broadcasting seed into *Hyparrhenia rufa* without any preparatory treatment; and in Nigeria, Foster (1961) established stylo in native rangeland by feeding the seed to cattle.

Although it is possible to establish some species without soil disturbance, quicker and more reliable results will be obtained if the surface can be broken, particularly in soils with hard-setting crusts.

Minimum Soil Disturbance

Where clearing is done with bulldozers, the soil in the tracks they leave will often be disturbed sufficiently to provide a suitable seed bed for pasture species. This is usually the case in heavily timbered areas, but if much grass is present, plowing of the grassy areas will be necessary to get even establishment.

When using bulldozers in steep country the drivers must be fully aware of the importance of not removing topsoil. Using rakes instead of blades when stacking timber helps, but the tree trunks themselves can push large amounts of topsoil ahead of them. The objective should be to roll the trees rather than push them and to form stacks on the contour as far as possible.

In general, large bulldozers are more economical than small ones, particularly if large trees are present. In steep country, however, two or three smaller machines working in unison are particularly effective. Smaller units are more maneuverable in tight corners, and if one gets stuck the others can help to extricate it.

Sod seeding and other partial cultivation techniques have been used successfully in open grass swards with some legume species such as centro (*Centrosema pubescens*) (Teitzel *et al.*, 1974) and siratro (Lowe, 1974). These methods are not recommended in grasses which form tight swards, such as carpet grass (*Axonopus affinis*) or kikuyu (*Pennisetum clandestinum*). Sod seeding is generally not as successful in the tropics as it is in temperate

zones, where winter growing species are sometimes seeded into summer species as they approach dormancy in the autumn. The existing vegetation does not then compete strongly with the young seedlings but this situation does not exist to the same degree in the tropics.

Full Cultivation

In steep country the aim of cultivation should be: (a) to eliminate all species which will compete with the sown pasture and (b) to break up the surface sufficiently to facilitate the entry of seed and moisture with the minimum amount of working.

A fine tilth is not necessary and will usually result in poor establishment. Erosion will be minimized and establishment will be quicker if the surface is left as rough as possible (Roberts, 1968). This allows surface-sown seed to be washed down into crevices, where the soil is damp. The germinating seeds are protected from direct sunlight and the emerging radicle can readily penetrate the loose surface.

Heavy tandem disc harrows can be operated on slopes of up to 25°. This is done by starting down a gully as close as possible to the watercourse, turning round the toe of the ridge and coming up the edge of the watercourse on the other side. By repeating this procedure each ridge can be cut out with the tractor working on firm ground all the time.

Chisel plowing should be done on the contour as far as possible, but on country which is too steep for discs the only alternative is to rip straight down the slope. If this must be done, it should be done early in the season and sown immediately to try to obtain a good cover before heavy rains commence. If erosion does occur, the viney legumes such as siratro, greenleaf and silverleaf desmodium (*Desmodium intortum* and *D. uncinatum*) or kudzu (*Pueraria phaseoloides*) do an excellent job of repairing the damage.

One working is usually sufficient, except in very tight grass swards. Additional working adds greatly to the cost and will result in a fine, fluffy surface which provides no entry for seed and will wash away even with light rainfall.

SEED MIXTURES

Frequent changes of soil type are a characteristic of hilly country. These may be brought about by changes in the parent rock, but even when derived from the same material there can be marked changes in soil texture, depth and moisture-holding capacity from the top to the bottom of the slope.

Pasture legumes are particularly sensitive to such changes. Hardy types such as siratro and stylo do well on the hard, infertile ridges; greenleaf and silverleaf desmodium on the hillsides; while species like glycine (*Glycine wightii*) and centro prefer the more fertile soils along the edges of streams, or soils derived from basalt. There are no clear dividing lines, however, and it is not possible to predict exactly which species will perform best in a given situation. In many cases mixtures of three or more legumes will be found growing in association, with one or the other predominating periodically according to the season.

Consequently it is wise to include several legumes in a pasture mixture on hill lands. In time they tend to sort themselves into colonies with species dominating in the particular soil conditions, or at the time of year, which suits it best. This spreads the growing season over as long a period as possible and also reduces the risk of the legume component of the pasture being eliminated by pests, diseases or unexpected climatic conditions such as unusually severe droughts or frosts.

On the other hand, it is usually best to use only one grass species in each paddock, so fence lines should be decided upon before sowing the pasture. Using two grasses in one paddock can create management problems, as cattle will eat the more palatable grass first. During this time the less palatable one becomes overmature, making it even less acceptable to cattle; it will only be eaten if very high stocking rates are used to the detriment of the associated legumes.

An exception to this is the use of a nonaggressive grass as a pioneer species in infertile soils. Molasses grass (*Melinis minutiflora*) is a good example of a suitable grass for this purpose. It grows well on infertile soils and controls weeds without unduly suppressing the legumes. Although it is not a particularly productive grass it provides good ground cover and some useful feed in the early years but it will not stand heavy stocking. Consequently, it will gradually be replaced by the more productive grass in the mixture as fertility is built up by the legumes and stocking rates are slowly increased.

When choosing seeding rates it should be borne in mind that on slopes it is seldom possible to provide conditions as favorable for germination as on flatter land. High seeding rates are not necessary for grasses, as they will thicken up quickly from their own seed; but increased seeding rates for the legumes will ensure a quick ground cover, reducing the risk of erosion in the establishment phase, and give early legume dominance which will simplify grazing management (Roberts, 1974). Legume seed should always be inoculated with the appropriate strain of nitrogen fixing *Rhizobium* to ensure early nodulation and fast growth of the seedlings.

SOWING METHODS

Sowing may be done by hand, by surface machinery or from the air. Because the quantities of seed used are quite small, of the order of 6–12 kg/ha, it is advisable to mix the seed with an inert carrier,

such as sawdust or rice husks, to increase its bulk and so obtain more even distribution. Superphosphate may be used for this purpose provided inoculated legume seed is pelleted and sown soon after mixing with the fertilizer. This is a useful method when hand seeding as the white fertilizer makes it easy to see which areas have been sown.

When broadcasting grass and legume seeds mixed with fertilizer, the legumes will be thrown farther than the lighter grass seeds, and some of the fertilizer will go farther then either type of seed. Seeding "runs" should therefore overlap to ensure even distribution. With aerial seeding half the seed should be spread over the whole area, in one direction, and then the other half applied at right angles to the original runs. If mountains prevent this, the normal swath distance should be halved. This should also be done if using ground equipment with spinner or blower type fertilizer spreaders.

Sowing with ground machinery is only satisfactory on moderate slopes—seed drills and broadcasting equipment do not work well at steep angles. On hillsides it is not possible to prepare the smooth seed bed required for accurate, shallow drill-sowing of small pasture seeds without running a great risk of erosion. Where drills are used, therefore, the seed hoses should be pulled out of the sowing boots so that the fertilizer is drilled in but the seed falls on the surface. Deep placement of seed is one of the most common causes of establishment failures, particularly with grasses. Seed should not be covered by harrowing—it tends to bury seed too deeply on a rough seedbed and leaves a loose surface which is vulnerable to erosion. If seed must be covered, dragging leafy branches or a light chain over the surface will sweep a small amount of soil over the seed without breaking up the clods.

Although it is a comparatively simple matter to establish pastures on steep country by the above methods, it must be remembered that maintenance fertilizer will be required regularly if the pasture is to remain productive. Provision must be made for easy delivery of fertilizer to the site, for example, by a system of vehicle tracks along ridges, or airstrips placed at an economical flying distance of about 5 km (Roberts, 1968).

TIME OF SOWING

If there is any marked seasonal variation in rainfall or temperature, it is advisable to sow slopes early in the growing season to obtain the best possible ground cover before the onset of heavy rains or cool weather. Plowing should be completed just before the early rains are expected. It is not necessary to wait until rain has fallen before sowing the seed—if heavy rain falls on newly plowed ground, a surface crust will form which prevents seed entry. Sowing should be done as soon as possible after plowing is finished and the surface is still loose. Pasture seeds broadcast on the rough surface of a dry seed bed can lie there for weeks without deteriorating appreciably. When germinating rain falls it will wash seed into the crevices where moisture is concentrated and conditions are suitable for seedling survival. Pelleting the seed helps to maintain good contact between the soil and any seed which remains on the surface, providing a pathway for moisture to move from the soil into the seed.

Once the radicle enters the soil, root development is rapid. The young seedlings have a remarkable ability to survive dry periods and early sowings seldom fail for this reason. On the other hand, very hot conditions may cause heavy seedling losses in later sowings (Kemp, 1976)

FERTILIZATION

Fertilizer requirements can vary considerably over quite short distances in hill lands. Nevertheless, a few general observations may help to avoid failures due to lack of understanding of the special nutrient requirements of tropical pasture legumes.

First, although N and P will almost certainly be deficient in most hill soils, N fertilizer should not be used on grass-legume mixtures. Henzell (1968) has estimated that effectively nodulated legumes will supply 62–180 kg N/ha annually to the associated grass. This will promote sufficient grass growth to keep it in balance with the legume. Any attempt to obtain additional grass production by applying N fertilizer will place the legume at a competitive disadvantage and, if persisted with, will lead to the elimination of the legume (Jones, 1971). The only exceptions to this rule are: (a) Small quantities of N, up to 50 kg/ha, may be used to assist establishment of grass seedlings on soils which are grossly deficient in N. (If this is done, the proportion of grass seed in the mixture should be reduced so that the grass will not smother the slower growing legume seedlings). (b) To obtain quick feed in an emergency up to 50 kg N/ha may be applied to a grass-legume pasture, provided this treatment is not repeated on the same area in subsequent years (Jones, 1970).

Some tropical legumes, for example *Stylosanthes* species, will grow in soils with very low levels of available P, of the order of 5–10 mg/kg (B.S.E.S. method) but much higher levels than this are required for good production. For example, Standley (1976) and Andrew and Bruce (1975) state that in the humid tropics of North Queensland pastures can be successfully established when available P exceeds 17 mg/kg and can be successfully maintained where it exceeds 30 mg/kg. These levels would seldom be found on tropical hill soils without the addition of P fertilizer.

Tropical legumes in general require higher levels of calcium (Ca), sulphur (S) and molybdenum (Mo)

than grasses. It is seldom necessary to apply lime to correct acidity on soils of pH 5.0 or above as most tropical legumes, with one or two exceptions such as glycine, are well adapted to low pH. They also have the ability to extract calcium from low Ca soils (Andrew and Norris, 1961). Sufficient Ca to supply the requirements of legumes on most soils is contained in the commonly used P fertilizers such as single and double superphosphate, rock phosphate and basic slag.

Sulphur and Mo are essential for good N fixation by legumes (Andrew, 1968). Single superphosphate contains sufficient S for most soils and should be used wherever it is available. Mo is only required in small quantities, 100 gm/ha is usually enough. It may be incorporated into a seed pellet (Roberts, 1968; Kerridge, Cook and Everett, 1973) or mixed with fertilizer.

Potassium may be required for establishment on hill soils with a history of previous cropping but as a rule soil disturbance during seed bed preparation may be expected to mineralize sufficient K for establishment purposes (C. S. Andrew, personal communication). For maintenance of a productive pasture the level of available K in the soil should be above 80–120 mg/kg (Standley, 1976).

Pasture establishment on old cultivated slopes is more difficult than on newly cleared land. Slower establishment and lower yields in the early years are usual, even though nutrient deficiencies have been corrected, and Roe (1974) suggests that this may be due to physical changes in the soil structure. This can be expected to improve under a grass-legume pasture—as has been demonstrated in northern New South Wales where good pastures have been established on abandoned banana plantations on steep hillsides (Roberts, unpublished).

WEED CONTROL

Weeds are seldom troublesome on newly cleared forest land, but there is usually heavy weed regeneration when old cultivations or forest regrowth areas are plowed. Repeated cultivation to destroy weed seedlings before sowing the pasture are not practical on hill land and are not necessary—a vigorous, dense pasture will suppress weeds if well fertilized and properly managed.

The viney tropical legumes will smother most weeds if they are allowed to. To enable them to do this they must be given time to climb up and over the weeds, weighing them down and cutting off light. Trampling with cattle or rolling will assist. If cattle are used, however, grazing must be carefully controlled to ensure that the legumes are not eaten back too far, otherwise they will be slow to recover and the weeds may get away again.

The main exceptions to the above are erect, woody species which cannot be weighed down by the legumes. These usually have to be butt sprayed or cut close to ground level and painted with 2,4,5-T in diesel fuel.

Some tropical legumes, such as greenleaf and silverleaf desmodium, stylo, glycine and centro, have good tolerance to 2,4-D at rates of from 0.8 to 1.6 kg/ha when well established, but siratro is very susceptible and at no time should this chemical be used on it. Herbicides containing 2,4,5-T or picloram are extremely damaging to tropical pasture legumes and as far as possible their use should be confined to spot treatments only (Bailey, 1969).

GRAZING MANAGEMENT

Early Grazing

Careful control of grazing in the first year of establishment is most important. To achieve this it is essential that all newly developed areas be securely fenced to exclude cattle and other herbivorous animals.

A few cattle should be introduced early enough to keep the fast growing grass in check and prevent it from shading the slower growing legumes. This will cause the grass to steel out and produce fresh, nutritious growth. As long as the grass is kept growing in this manner the animals will eat it in preference to the tropical legumes which, with a few exceptions, are less palatable when young. If stock numbers are kept low enough for the animals to satisfy their appetites by eating grass tips only, the legumes will quickly establish a good ground cover.

The objective should be to adjust stocking rates to achieve legume dominance as quickly as possible. Legume dominance, in this context, is defined as the stage of growth in a mixed grass-legume pasture where the legumes have overtopped the grass and have obtained an advantage in competition for light. At this stage there will be very little grass visible and the pasture will appear to be all legume, but in fact there will usually be only about 20–30% legume in terms of dry matter.

Animal production is positively correlated to the amount of legume in the pasture (Evans and Bryan, 1973). In practice, however, it is difficult to maintain a higher proportion than about 30% of legume dry matter under grazing. It follows, therefore, that for maximum animal production the pasture should be managed so that it will always appear to be legume dominant. With most tropical pastures the feed will be about knee high at this stage and most cattlemen would consider it to be undergrazed—but this big reserve of feed is necessary for quick pasture regrowth to prevent weed invasion and also to protect the slopes from erosion. Any attempt to utilize all the feed on offer will soon lead to a decline in pasture quality and lower animal production.

Stocking Rate

Stocking rate is the most important factor affecting the stability and long-term productivity of a grass-legume pasture. Overgrazing will lead to a decline in the proportion of legume in the pasture and this will be followed by a sharp fall in animal production.

This is illustrated in Fig. 1, which is based on the results of a grazing experiment which compared animal and pasture production from three sub-tropical pastures at various stocking rates in southeastern Queensland (Jones, 1974a; and 1970–75). On a mixed pasture of greenleaf desmodium and Nandi setaria (*Setaria anceps*) at a low stocking rate of 1.11 animals/ha the grass and legume formed a stable association of approximately half grass and half legume with very little weed (Fig. 1a). At the high stocking rate of 2.96 animals/ha the legume had been reduced from 23% to 6% after three years, with 46% weeds (Fig. 1b). On a siratro/setaria pasture in the same experiment the trend was similar but not quite so pronounced, possibly because siratro will regenerate from its own seed more readily than desmodium.

The effect of these botanical changes on animal production is shown at the bottom of Fig. 1. At the lower stocking rate liveweight gains per head and per ha remained fairly constant over the four years of the experiment, with a mean annual liveweight gain of 200 kg/ha and 180 kg/head (Fig. 1c).

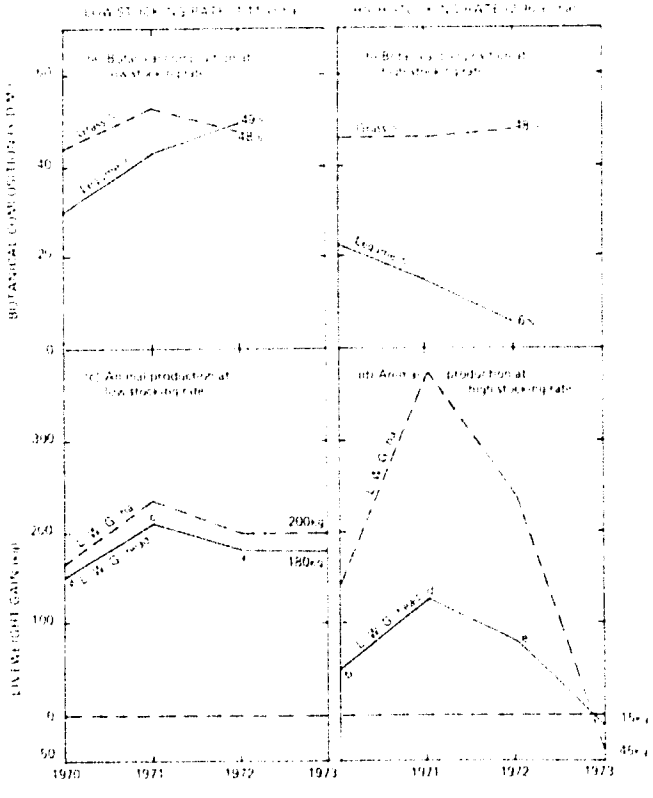

Figure 1. Performance of a greenleaf desmodium/Nandi setaria pasture over four years at two stocking rates (after R. J. Jones, 1970–75).

At the higher stocking rate there was a steep increase in liveweight gain in the second year but this was accompanied by a decline in legume percentage, which led to dramatic falls in liveweight gains in subsequent years. In the fourth year there was practically no legume left in the pasture and the animals actually lost weight (Fig. 1d). Over the four-year period the mean annual liveweight gain on this treatment was only 178 kg/ha and 58 kg/head.

At the higher stocking rate production over the four-year period was 88 kg/ha lower than it was at the low stocking rate and production per head was not satisfactory at any stage. Not only had there been a loss of production but the legume component of the pasture had been eliminated at the high stocking rate and further falls in production were inevitable.

Emphasis has been placed on this because overstocking is the most common cause of failure in tropical grass-legume pastures. Managers are misled by the apparent abundance of feed available and by the belief that higher stocking rates will give higher profits. This is not necessarily true even in the short-term because, though production per ha may be temporarily increased, income will not increase in proportion. This is because the yield of saleable meat is less from a slow growing animal and it is also of inferior quality, so increases in yield on a liveweight basis may be completely offset by reduced prices. Thus, overstocking will result in an immediate lowering of quality, followed by a continuing reduction in quantity of animal products, and eventual destruction of the pasture.

The safe stocking rate for any given pasture will be governed largely by rainfall and the length of the growing period. The safe rate of 1.11 animals/ha quoted above was obtained in a subtropical climate, with average rainfall of 1625 mm and light frosts in winter, and a growing period of 6–7 months. About 100 km farther south, in a frost-free situation and annual rainfall of 1750 mm, with a slightly longer growing season of 7–8 months (Roberts, 1973), stocking rates of 1.5 animals/ha have now been maintained for six years. It is expected that in the wet equatorial climate of West Malaysia, with well-distributed rainfall and potential for growth in practically every month of the year, stocking rates of up to 1.75 animals/ha can safely be maintained on adequately fertilized and well-managed grass-legume pastures when fully established (Kerridge, 1975).

At stocking rates of this order beef can be produced from tropical grass-legume pastures more cheaply

than it can be from N-fertilized grass pastures on present fertilizer costs.

It is important to appreciate that stocking rate alone does not give a fair indication of the productivity of legume-based pastures. For example, seeding Townsville stylo (*S. humilis*) into native speargrass (*Heteropogon contortus*) pastures in Queensland, and fertilizing with superphosphate, has increased the stocking rate of steers threefold and liveweight gain per ha sixfold (Shaw and 't Mannetje, 1970) and has also produced increases in conception rates and calving percentages (Edye *et al.*, 1971). Thus the big gains in animal production result from increases in yield per animal, which is a function of pasture quality, as well as increases in stocking rate, which is a function of pasture quantity.

Grazing Systems

There is a widespread belief that greater animal production can be achieved under a system of rotational grazing than under continuous grazing, but there is no evidence that this is true of tropical pastures. 't Mannetje, *et al.* (1976) summarized the results of 15 experiments on tropical pastures which compared various grazing systems. They showed that productivity under continuous grazing is as good as, and sometimes better than, several forms of rotational grazing.

In one of the experiments quoted by the above authors, in Rhodesia, conception rates were far lower with a short-duration rotational grazing system than with continuous grazing. For breeding stock, therefore, the choice of grazing system may have important long-term effects which are not revealed by the usual method of measuring liveweight gains of steers. It is probable that the higher conception rates with continuous grazing were due to the fact that under this system the animals had greater freedom to select the most nutritious portion of the feed available at any given time.

Most of the tropical pasture legumes in common use are vines which should not be grazed too low. Frequent severe defoliation will seriously reduce their vigor and may result in their death (Jones, 1974b). Their comparative unpalatability during early stages of growth gives them a degree of protection against overgrazing in a mixed grass-legume pasture if animals are allowed freedom of selection. Under a rotational grazing system animals have less opportunity to select their diet and they are forced to eat a greater proportion of the legume than they would under a continuous grazing system. (An exception to this is the tree legume *Leucaena leucocephala* which is so palatable that cattle will graze it out if given continual access to it.)

Even in a simple two-paddock system the stocking density is doubled on the paddock which is being grazed—with a resultant increase in damage to the legume from trampling and plugging of the soil in wet weather. Also, in paddocks which are not being grazed, the faster regrowth of the grass will cause shading of the legume and further slow its growth.

All these factors will reduce legume yield and persistence. In practice the effects are usually more pronounced than they are under research conditions. There is always a tendency to leave cattle in a paddock as long as there is still some feed there. Grazing the pasture right down to ground level may not harm the cattle but it can do irreparable damage to most tropical legumes. The only exceptions to this are a few low growing legumes such as lotononis (*Lotononis bainesii*) and hetero (*Desmodium heterophyllum*) which are not in widespread use. Like clover, these are more productive and persistent if the pasture is kept short.

In view of the high cost of fencing and providing water in small paddocks on hill lands the extra cost of rotational grazing systems cannot be justified. Only sufficient subdivision should be done for convenience in cattle management.

It should be pointed out that in the above context continuous grazing is not the same as set stocking. It simply means that there are normally some cattle in each paddock at all times. Although total cattle numbers may not vary much throughout the year, the number in each paddock may be varied from time to time according to relative availability of feed, but cattle are never completely removed specifically for the purpose of promoting pasture regrowth.

Under this system, at the correct stocking rate, animals will graze quite steep slopes remarkably evenly. They camp on the ridges at night, where it is cooler in summer and warmer in winter. In the morning they slowly graze down the sides of the hills, camp near water in the middle of the day, and gradually work their way back up the slopes in the afternoon. This pattern of grazing establishes a system of contour tracks, or mini-terraces, across the face of the slope at intervals of about 1.5 m. The pasture between the tracks is grazed with a minimum of damage by trampling and permits dense "hedges" of pasture to form which effectively check erosion.

The Place of Pure Grass Pastures

Because legume based tropical pastures are sensitive to overgrazing, managment can be considerably simplified if some paddocks of pure grass pasture are included in the system. These should be located in those areas which must at times be subjected to heavy stocking densities, such as around stockyards and dairy buildings. The most suitable species for this purpose are grasses which utilize applied N efficiently, and which form dense swards that are resistant to trampling and over-grazing, such as signal grass (*Brachiaria decumbens*) and kikuyu.

These paddocks can be used as a "safety valve" to relieve pressure on the legume-based pastures during periods of temporary feed shortage. The optimum ratio of pure grass to grass-legume pasture will depend largely on the length of the growing season. A system employing about 25% of pure grass pastures has been successfully used in northern New South Wales for the past six years (Roberts, unpublished) and a somewhat similar system has been advocated for use in North Queensland by Tietzel *et al.* (1974).

The management of pure grass pastures in the humid tropics has been fully dealt with by Vicente-Chandler *et al.* (1974).

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17.
Andean Culture and Agriculture: Perspectives on Development

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During the last twenty years, economic development has been a central theme in the Peruvian Andes. During the last decade, adaptation has been a major motif in anthropological studies, and we have come to understand Andean culture as an adaptive mechanism in the mountain environment of Peru. Still before us is the task of weaving together the theme of development and the understanding of cultural adaptation. The thrust for development looks toward an uncertain future while the study of adaptation offers lessons from the past. Whether these can effectively be bridged remains unanswered. My research in the Peruvian highlands indicates that peasant cultivators there follow a set of adaptive strategies which reduce the risk of erosion and crop loss in a highly diverse and unpredictable environment. I will outline these strategies and discuss their relation to development programs in the area.

In the Peruvian Andes, where traditional agriculture predominates, peasants deal with one of the steepest environmental gradients in the world. Single mountain slopes often span several thousand meters in altitude, embodying numerous local microclimates and plant communities. Altitude is critical to a number of interrelated environmental factors: temperature, rainfall, exposure, slope, drainage and soil composition. Botanists and geographers have long recognized that these features produce numerous ecological zones related to elevation. Dense stands of tropical montane forest cover the eastern slopes at 1 800 m; above 3 600 m sedges, bunch grasses and thick tundra-like sod predominate; and in intermontane valleys, a thorn and scrub forest manages to survive permanent drought.

Anthropologists, archeologists and ethnohistorians have recently studied the relationship between this complex ecology and native Andean culture. Their work clearly demonstrates that peasant agriculture, as well as great civilizations, such as the Inca Empire, may be understood as systems of ecological control spanning the Andes from the dry Pacific coast to the dense jungles of the eastern foothills. Prehistorically, the Inca administration moved groups, known as *mitmaq*, into different parts of the Empire to produce certain crops such as coca, the mild Andean narcotic used for ritual, medicinal and pain-relieving purposes. Today some villages control single valley systems with a wide range of ecological zones, while inhabitants of others make several annual treks between widely dispersed zones. The typical Andean household depends on the resources and crops of several major production zones for its subsistence.

The native populations of the Andes organize much of their economic activity around the resources and products of four major crop zones. Access to these may be sought in two ways: direct exploitation or exchange. The four zones are:

1. A tropical zone (known as the *Yunga*, *Temple*, or *Montaña*) which produces fruit (such as oranges and bananas), tropical root plants (such as manioc), chile peppers and, perhaps most importantly, coca. (Altitude—240-1 500 m.)
2. A middle level mountain zone (known as the *kichwa*) where maize and wheat are grown. (Altitude—1 500-3 000 m.)
3. A relatively high mountain zone (known as *puna* or *jalka*) where the staple of the Andean diet, potatoes, and other Andean tubers are grown. (Altitude—3 000-4 000 m.)
4. A high mountain zone (known as *puna* or *jalka fuerte*) where Andean cameloids (llama and alpaca) as well as sheep, horses and cattle are grazed on natural pasture. (Altitude—above 4 000 m.)

The products of these zones constitute the fundamental subsistence base of the native Andean populations, and access to them is essential to life in the Andes. The type of access to these products varies from village to village, but it usually involves a combination of ownership and production of some fields, yearly migrations, personal exchange networks and market participation. Individual peasants use this combination as a set of subsistence strategies in order to maintain an adequate standard of living.

In analyzing Andean adaptation, it is possible to identify three general types of traditional economic systems corresponding to the regional pattern of environmental gradients (Brush, 1976). In areas of steep gradients, self-sufficient communities exploit these four production zones without markets or migrations. In other areas, people migrate yearly between different zones. In areas of relatively gentle environmental gradients, elaborate market systems integrate these production zones.

Individual households in a particular village may employ a wide number of strategies to secure an adequate subsistence. This is evident in the village of Uchucmarca where I have done field work (Brush, 1977). Uchucmarca is a corporate peasant community which owns a single Andean valley system in the Marañón drainage in northern Peru. This valley spans over 3 000 m in altitude and includes all four of the major Andean crop and production zones. The valley begins in a hot, arid intermontane zone at roughly 1 000 m and climbs to a rain tundra over 4 500 m. The valley running between these extremes is less than 70 km long and may be traversed in one long day's travel by horse or mule. In one day's ride it is possible to pass through climates as diverse as those between west Texas and Alaska. Riding farther, one drops down through cloud forests of the eastern Andes along tributaries of the Amazon River.

The central village in the valley is eight hours from the nearest road. It is economically isolated from the national economy of Peru by narrow horse trails and by the fact that the village is virtually self-sufficient in producing its own subsistence. Peasants there recognize and name seven different production zones in the valley which are variations on the four major zones mentioned above. Adequate resources in each of them permit the village to meet the needs of its population. The village economy may be understood as a set of subsistence strategies designed to provision each household with adequate food. These include labor exchange, payment in crops as well as cash, direct product exchange between zones and a system of sharecropping which exchanges land for labor. One of the most important features of the local economy is that it is able to function as a largely nonmonetized economy. The average family in Uchucmarca needs less than $100 yearly to buy the few goods which it needs and cannot produce directly or trade for.

Three hazards which peasants in Uchucmarca and elsewhere in the Andes must cope with are erosion, climatic variation and crop destruction by diseases and pests. The threat of erosion comes partly from human activities—grazing or cultivation which destroys protective plant cover. Climatic fluctuation threatens agriculture in two ways: frost and unwanted rainfall patterns. Minor variations in expected patterns can disrupt or destroy fields in one of the micro-zones. At the lower end of the valley, drought is a constant threat. Higher up, toward the upper limit of cultivation, frost or overly abundant rainfall which brings on late blight are threats to potatoes, the staple of the highlands. Finally, disease and pests are constant threats to these people, who farm without using chemicals. To meet these threats, Andean peasants follow a number of strategies.

The danger of erosion is avoided in three ways. First, fields are kept small—usually less than 1/2 ha. This is possible because individual households cultivate primarily for their own consumption, rather than for sale or exchange. One or two small fields in each of the production zones is sufficient to meet an average family's needs. A typical family of four or five cultivates between 1–2 ha, spread among three or four fields. The small size of individual plots retards runoff and erosion. Second, each field is surrounded by a hedgerow constructed of rocks, brush and living plants. Ostensibly built to keep out destructive livestock, these rows effectively limit erosion. Their roots hold the soil, and horizontal plowing behind them tends to build up soil at the lower side of the field. This creates a quasi-terrace or lynchet which retards runoff considerably. Third, field rotation is practiced in the highest and steepest part of the valley where rainfall is heaviest and erosion most likely. Potatoes are cultivated under a regime of shifting cultivation in which fields are only planted for two or three years before being returned to a long fallow of five years or more. By using this method, the amount of soil washed off of fields is limited, and organic material is allowed to accumulate.

The Andean peasants have learned to cope with climatic variations that disrupt crops in narrow agroclimatic zones. The exploitation of multiple zones and crops is the major way of avoiding catastrophe if one crop is destroyed by drought or frost. Another way is to plant several different fields of the same crop, hoping that at least some of them will survive. These means are reinforced by systems of economic reciprocity and mutual dependence which rely primarily on the kinship system. My research demonstrates how individual households protect themselves from privation by exchanging land, labor and goods (Brush, 1975, 1977). This is done largely without the use of cash.

Finally, Andean peasants meet the threat to their crops from insects and disease by maintaining genetically diverse crop collections. This is especially true of potatoes. The potato was originally domesticated in the central Andes, and the area is the source of tremendous diversity in that crop. Botanists estimate that there are over 2 000 potato varieties in Peru alone. In single villages like Uchucmarca people identify some 50 varieties, and in some areas up to 100 local varieties may be found (Hawkes, 1967). Moreover, botanical evidence indicates that new varieties are constantly created through cross-pollination between cultivated, wild and semi-domesticated (weedy) species (Ugent, 1970). These wild and semi-domesticated species thrive in the hedgerows around fields, and birds and insects living there assist cross-pollination. By maintaining the large inventory of potato varieties, Andean peasants avoid genetic vulnerability to disease and pests to

which homogeneous fields are liable (National Academy of Sciences, 1972).

The potato is plagued by frost and a wide variety of pests, the most destructive being late blight, other fungi, viruses and a host of potato leaf hoppers and worms. Living in isolated, nonmonetized economies, peasants usually cannot afford and are often ignorant of chemicals to control such pests. In most traditional communities, such as Uchucmarca, a first line of defense is drawn against these by maintaining as wide a genetic base as possible and by selecting different types more resistant to frost, blights and insects. No single variety is able to withstand all of these, and no one has total resistance to any single pest. But growing many varieties lowers the risk of hunger if one field or variety is attacked by a particular pest. In Uchucmarca, a common practice is to plant fast growing varieties during the drier part of the year so as to avoid late blight which increases during the months of heavy rain. Another practice is to cultivate certain varieties believed to be somewhat frost resistant in flat, bottom areas of the high valley where frost but not late blight is common. Other varieties are chosen for hillside cultivation where late blight but not frost is common. Other qualities which differ among potato varieties is how well they do at different altitudes and whether they need well drained soil.

Besides the protection afforded by genetic diversity in numerous potato varieties, the long fallow cycle controls disease by killing vectors which remain in the soil and depend on continued potato plantings to survive. Serious potato diseases which may be retarded or eliminated by fallowing include nematodes and fungus diseases such as potato scabs, dry rots and wilts.

The people of Uchucmarca have succeeded in establishing an economy which satisfies their subsistence needs. The economy has considerable complexity and sophistication—a highly diversified resource base, an elaborate set of strategies to tap and distribute these resources and a variety of means to reduce subsistence risk. Their economy is relatively independent of the monetized market economy of Peru and the world, and their technology enables them to exploit this Andean valley without eroding the steep hillsides which they farm. These accomplishments belie the conventional descriptions of peasants as simple and backward.

Although Andean peasants in Peru appear to have successfully adapted to various environmental hazards, neither their agriculture nor economy is static. Changes are occurring from two related directions. First, there are increased pressures within peasant villages for change. Significant factors here include growing populations and rising expectations. Second, pressures emanating from the national economy of Peru result in changes in remote villages like Uchucmarca. Examples of these are road building programs, market development and the demands of fast growing urban areas.

One change that looms above traditional peasant agriculture in the Peruvian highlands is the development and promotion of high-yielding agricultural technology related to the Andean staple, potatoes. Improved varieties, capable of yields two or three times greater than those of traditional varieties have been available for almost two decades. These varieties predominate in some areas of large commercial production, and they have diffused widely into remote villages. Agro-chemical technology to fertilize fields and control diseases and insects has also begun to spread into highland villages, partly due to extension programs. The Peruvian government and international development agencies initiated efforts to increase the use of these high-yielding varieties and agro-chemical technologies. As part of the worldwide demand to accelerate food production, the International Potato Center was established in Lima in 1971.

The continued diffusion of new varieties and agro-chemical technology seems certain in the Andes. From an anthropological perspective, I believe that a number of important lessons can be learned from traditional Andean agriculture as this development proceeds.

It is apparent that peasants in traditional villages have resisted conversion from native Andean potato varieties and cultivation techniques to the high-yielding ones for a number of reasons. First, and most important to the people themselves, the new potatoes do not taste good, and their watery consistency is unpleasing to people who prefer mealy potatoes. They also think this is true of potatoes grown on fields which have been chemically fertilized. Good tasting potatoes, by Andean standards, are incompatible with heavily fertilized fields. Second, peasants maintain that their ancestral varieties are more satisfactory as food. Information published by the International Potato Center seems to corroborate this (Bacigalupo, 1972). Traditional varieties, especially the favorite floury textured ones, tend to be higher in protein and better in protein quality than improved strains. Crude protein of the native types averages roughly 2.5% versus 2.1% for the new types. In terms of protein equivalency ratios, which measure protein quality, some of the native varieties are over 50% higher than the most commonly planted improved variety.

Third, the high-yield technology, especially the agro-chemicals, is generally too expensive for peasant cultivators. Private loans are scarce, and public loans usually unavailable in remote areas. The scale of potato production in peasant villages does not now justify long and expensive trips to secure credit. Moreover, typical peasants are accustomed to pro-

ducing potatoes with little or no cash expenditure. In Uchucmarca, for example, the average annual investment per plot is less than two dollars to hire a team of oxen for two or three days. Outside labor, if needed, is traditionally paid for with the crop itself. In commercial production in other parts of Peru, per-acre investment is around $175, with roughly $60 going for chemical fertilizers, insecticides and fungicides. Similar investment is clearly beyond the means of peasants in villages like Uchucmarca. The small cash reserves of most households are needed elsewhere: to buy school uniforms or medicines or to pay for a child's secondary education away from the village. The conversion to potato cultivation based on cash investment, credit and marketing represents a total shift in the perspective of the peasant. Such an investment would be highly risky, as the people of Uchucmarca have indicated to me. Transportation time and cost from this isolated village market make local potatoes uncompetitive in market centers. Moreover, the potato market in Peru is highly unstable so that return profit and the ability to meet creditors' demands is far from guaranteed. Uchucmarquinos also point out that the persons who bought their small potato surplus in the past prefer the old-fashioned varieties grown on unfertilized fields and will refuse the new varieties grown on fertilized fields.

These are the reasons cited by the people themselves for not adopting the new potato varieties and chemicals. From an outsider's viewpoint, we can discern two general reasons why this decision by the peasants of Uchucmarca is a sound one. The first relates to genetic vulnerability when a few new varieties replace numerous ancient ones, and the second concerns economic vulnerability when a new and alien technology is adopted.

Botanists Donald Ugent and Hugh Iltis have described the highly diversified potato fields of native Andean peasants as "homeostatic systems" which are the result of thousands of years of natural and human selection (Ugent, 1970). They argue that the encroachment of modern varieties may weaken or destroy the ecological viability inherent in such a system by greatly reducing the genetic base and by replacing local varieties with foreign ones which do not share the ability to cross-pollinate with wild species. If today's subsistence farmers become tomorrow's commercial producers, the low-yielding native varieties may well become economic casualties. I have observed this replacement not far from Uchucmarca where new varieties are cultivated to the exclusion of old ones. Similar losses to ancestral gene pools have been widely reported in areas where high-yielding varieties replace traditional crops (Harlan, 1975).

The loss of this rich gene pool of indigenous varieties forces the farmer onto an ecological high-wire where the narrowly based genetic crop may fall prey to a recently evolved disease. Omens of such disasters are plentiful: the 1970 corn blight in the United States, coffee blights in Brazil and the Irish potato famine of 1845. Further reduction in the gene pool of indigenous varieties may severely limit our ability to respond to such genetic dangers.

The developers of new high-yielding varieties are aware of this danger and have countered it by creating germ plasm banks such as the U.S. Government station at Fort Collins, Colorado, where seeds are frozen. Such methods are satisfactory, provided that the seeds remain viable under such conditions and that the machinery for keeping them does not fail. Recognizing that neither of these provisions are certain, Iltis has proposed "freezing" selected genetic landscapes by setting aside "cradle" regions where specific crops are off limits to agricultural improvement. Such a proposal has the merits of avoiding accidents such as power failures and allowing the natural on-going process of cross-pollination between wild and domesticated species to continue. For potatoes, Iltis (1974) recommends the establishment of the International Potato Diversity Preserve in the Lake Titicaca basin of Peru and Bolivia.

Like the native potato fields, the economies of traditional villages are relatively stable, if low-yielding, systems. They also are products of a very long process of selection which began before the Spanish conquest. The adoption of new high-yielding crop varieties and agro-chemical technology depends on restructuring traditional cultural and economic patterns. One such pattern which has diminished in areas where new varieties and technology have been adopted is diversification of fields and crops in multiple zones. During a survey north of Uchucmarca in 1974, I observed areas where the shift to commercial potato production resulted in the abandonment of lower zones and crops, especially maize. This had been done in order to specialize in the production of one crop, potatoes. The adoption rests on speculation concerning two conditions: first, that the potato market will continue to be profitable to the farmer; and second, that the economic infrastructure of rural Peru will be able to supply necessary tools, chemicals, credit and technical assistance at reasonable costs. Traditional peasant agriculture depends entirely on local energy and resources; while the new system depends on external subsidies of cash, energy, chemicals and other resources. Keith Griffin (1974) notes that services such as credit and rural assistance which support the agricultural modernization are often biased away from the peasant in favor of large commercial producers. Ernistine Frankel (1971) has observed the effects of this bias in India where the living standards of the poorest peasants have deteriorated in some areas and where

traditional peasant relationships have been undermined after the introduction of advanced agricultural technology. If these services and subsidies fail, the peasant may have no alternative but to join the rural exodus to cities.

There are three lessons which we might draw from the example of Uchucmarca as new crop varieties and advanced technology diffuse into more and more peasant societies. First, developers should be aware of the long-term adaptations of peasants and must strive toward incorporating these into their schemes for "improving" peasant agriculture. The new agrarian technology must be cognizant of and include native practices which have provided a stable subsistence base and reduced the risk of erosion. Second, the creation of new potato varieties should not be accomplished at the expense of genetic reserves of the older varieties. Seed banks and reserves of native varieties should be an important part of the new agrarian technology. Likewise, since stability is enhanced by having many varieties, those wishing to raise yields should also strive toward maximizing the number of varieties which peasants grow. High quality native tubers should not be excluded from the package of "improvements," and yields should be increased by methods other than complete displacement of these varieties. Finally, the planning and financing of the new agrarian technology must include a peasant-biased infrastructure to ensure the provision of necessary credit, materials and assistance to those peasants who become commercial producers. Without this, peasants risk the danger of becoming tied to a system which may fail them at critical times.

The passing of traditional cultures such as the life of peasants in remote corners of the Andes means that the wealth of cultures in the world is lessened. This passing seems inevitable. What is not inevitable is the loss of important insights and resources possessed by these traditional cultures. These lessons are essential for the future of our hungry planet, a future made more precarious if they are lost along with the cultures which hold them.

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DISCUSSION

Wendell Berry (Pennsylvania, USA). Is the population level sustained by traditional agriculture in those areas? Could you talk about the traditional methods of fertilization?

Brush. It is very difficult to answer the first question specifically. As in most peasant areas, there is net migration away from the Peruvian highlands. Agricultural production, since it is subsistence production, is tied to the level of population which we find there. There is much evidence that the same type of agriculture supported a much denser population pre-Hispanically in the area.

Now, as to native systems of fertilization, the only native systems in the Andes which have been going on since before the Spanish conquest are the use of guano fertilizer from the coast and, more importantly, the use of natural animal fertilizer. In the village where I worked the sheep were penned in the potato fields between the first and second year—penned in one field for one or two nights. But, generally, with the system of field rotation and shifting cultivation, heavy fertilization is not considered to be one of the necessary elements of potato cultivation.

Berry. Do they compost?

Brush. No.

Berry. Do they use human wastes?

Brush. No.

Unidentified. Would composting occur?

Brush. That's a good point. Yes, potato cultivation starts above 3 300 m, so composting would be difficult.

Bob Chapin (Mississippi USA). We've been trying to estimate how many acres it takes to support a Mississipian and we've come up with a preliminary figure of 2.73. I was quite interested in your figure of 3 1/2 acres per family as a subsistence level in a very arid and high-altitude place. Could you tell me what other uses of land occur in these primitive areas?

Brush. In that figure I did not include grazing land. Roughly 40% of the land in the valley is used for open pasturing. Meat consumption is a part of the

diet, certainly less important than in the average American diet, but that would be a hidden factor in the amount of land necessary and I really don't have the data to calculate the amount of grazing land in that figure.

Chapin. What about hunting and fishing area?

Brush. Hunting is not important for subsistence. Fishing plays a minor part. If you calculated in house plots you might add another 1/2 acre or a quarter of an acre per family. Often small gardens are maintained around the house.

Unidentified. What do they use for fuel?

Brush. Firewood. In this area, as in other parts of the Andes, it's a very rapidly decreasing resource. There is virtually no firewood on open slopes. It's primarily from ravines and small gullies.

Edwin Oyer (New York, USA). In regard to the firewood, you mentioned the windbreaks and the erosion control. I would hope that these would be used as firewood and I'm interested in the species and if they are part of the farming system. Secondly, going back to the question of the subsistence level of agriculture and the population balance, you mentioned that there is an ex-migration from the subsistence villages to the cities. Obviously these people still need to be fed and I presume they still eat potatoes. What is the Peruvian government doing or what do you see is the possibility of increasing production in some place in some part of the country to handle this larger urban population that develops?

Brush. One family gets very upset if another family comes to their hedgerow and starts chopping firewood. They don't usually go to hedgerows to cut firewood. In terms of feeding urban migrants, Peru relies primarily on commercial production on the coast and in some of the central valleys in the highlands. Peru also imports a great deal of food, especially wheat from the United States. So far, they haven't tapped the resources of subsistence agriculture. I don't have exact figures on what percentage of urban food comes from primarily subsistence areas but it's fairly small. The question is how to hold people on the land. For a long time Peru has had fiscal and monetary programs to attract people out of the highlands under the belief they are severely underemployed or unemployed. There are figures published in Peru that argue that there is up to 60% unemployment or underemployment. My work in peasant economics in the highlands indicates that the real level of disguised unemployment is around 6 or 7%, something like our own country. But Peru and many other underdeveloped nations have been operating under the assumption that this underemployment exists—that you have idle labor and that the government should try everything possible to attract people out of the highlands. This may mean that they don't extend extension services, schools, hospitals, roads and so forth under the belief that life should not be made attractive in the highlands. I certainly believe it is time to start reassessing these beliefs and try to hold people in the highlands. While I won't argue for the maintenance of subsistence agriculture, I certainly will for small-scale commercialized agriculture. I think the model that the man from Sri Lanka was talking about yesterday is a very attractive one for nations like Peru.

Earl Leng (AID). I have a comment first, that probably will show one of my biases, and then a question. I don't mean to criticize the organizers of this symposium, but we've got all the geneticists next door talking about one thing, the economics group in here talking about another, and we really ought to be talking to each other. I am a plant breeder by trade, yet I think the question of genetic vulnerability has been overemphasized. We had a conference on genetic vulnerability in New York in the spring, and, while there is a good deal of concern about it, the answer is not necessarily in maintaining the whole spectrum of plant material and maintaining the peasant in his completely underdeveloped or undeveloped stage as to what it is he's growing. It is possible, I think, to have adequate genetic protection without going all the way to one variety on the one hand or without staying in Hugo Iltis' state of the "genetic park" on the other. Now the question is, what's the perception of the local villagers about development? Do they really want something to change in the village where you work or are they satisfied with life as it is there? I think governments ignore this a lot of times and I'm particularly concerned about this for Peru because there are some development schemes going on of which I am aware. I have rather serious reservations about whether the Peruvian peasants really are going to take them up—whether they will have any desire at all to do this kind of thing. I would like to know for the village where you had your experience what the perception is?

Brush. That's a difficult question to answer. It is a dirty question because whether the people understand what development means for them is the whole crux of the matter. Yes, they do want development. They want things like roads, schools, hospitals. I don't mean to idealize the peasant way of life; above all a peasant way of life means a shorter life span, harder work, more illness, less opportunity for your children and for yourself, and so forth. On the other hand, what type of package is presented to the peasants? Usually for them, from a personal point of view, development means leaving the way of life in which they were born and going to the city. Many of them express the desire to have development come to the village, and yet they seem to perceive their

inability to do anything about this themselves. They wait for the government to do something to bring development to them. I often wonder whether their inaction in terms of developing their own local economies may be a hidden recognition that their traditional way of life is a pretty satisfying one.

Susan Almy (Rockefeller Foundation). You were dealing with a Conquest state where there is a big gulf between the people who would be extension agents and credit agents and all the rest who would be peasants. The Peruvian cooperative systems apparently haven't worked very well trying to get the peasants to run their own support systems and I was wondering if you have any ideas on what kind of support system you would use that would manage to bridge this if you really wanted to get into that area?

Brush. There are two levels of co-ops in Peru. One is the essentially state farm co-ops on the coast using export crops, sugar, cotton, and rice and so forth. The other one is an integrated regional cooperative plant which was begun fairly recently, only in the last four or five years, and there are only a handful of regions in the highlands which have these integrated regional co-ops. There was no cooperative development in the area that I worked in and I don't currently have enough information to say the plan looks good. After the land reform, it was felt that the land tenure system in the highlands was not a local problem but a regional one. Reform and development must take a regional approach rather than a local approach. So they started with these regional cooperatives.

18.
Social Organization of Peasant Farming in Mountain Areas of Mexico

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The Mexican agrarian structure presents a sharply contrasting image, with a large poor peasant population, and a few flourishing capitalist agricultural enterprises.

The latter monopolize the major part of the rich, fertile, well-watered lands; they use modern technology but also employ many temporary workers in a production process primarily directed towards the satisfaction of the international and the high-income national markets.

At the opposite extreme, the peasant families till small plots of mostly "temporal"[1] lands, with a rather backward technique which sometimes does not even include the plow; they devote a large part of their production to their own consumption, with the remnant—which is not necessarily, and not even usually, a real "surplus"—being sold at the local market.

The 100 000 production units which may be classified as capitalist (those which produce more than 25 000 pesos a year as reported by the V Censo Agricola y Ganadero carried out in Mexico in 1970) produce 52.2% of the national agricultural production by value, while the 2.6 million peasant farms produce the other 47.8%. (Peasant units are both the private and the commonly possessed plots which produce 25 000 pesos or less a year.)

But, if we also take into account the distribution of the land, particularly that which is tillable and irrigated, or the producers' access to credit, or even information on the general infrastructure (communications, electricity, schools, commercial facilities, technical advising, etc.) developed in each region, we would then recognize that the key criterion for a comparison between the capitalist and the peasant farms may not be that of efficiency, but rather the availability of the necessary resources.

For instance, the capitalist units, which represented 3.3% of the agricultural production units in the 1960 census, used 42.7% of the tillable lands and 69.1% of the irrigated ones, and owned 75% of the total agricultural tools and machinery value. In view of the enormous concentration of lands and capital they benefit from, their share in the value of the national agricultural production (54.3% in 1960) does no longer appear as such a good performance, and even suggests that the average capitalist unit

[1] The temporal lands are not irrigated and can be cultivated only during the rainy season (May-October).

is less careful in exploiting its resources than the peasant unit is. (Although these figures, estimated by the Centro de Investigaciones Agrarias (1974) for 1960, have not been applied yet to the 1970 census, the available data on the land distribution process until 1968 show that they depict the 1970 situation accurately.)

There is no adequate information for a quantitative analysis of the access to credit, in terms of capitalist and peasant farms. However, it is well known that the general profit-seeking character of the private credit institutions and the prerequisites they impose on those who apply for a loan (presentation of legal documents proving ownership of the land, ascertained solvency, etc.) reduce their potential clientele to the medium and big capitalist enterprises.

The official agrarian banks, on the other hand, are meant to lend money to the "ejidatarios" who possess but do not own their plot, and to the small private owners. They reach only a small part of them, yet, and mostly agree to short-run loans, which help their clients to survive indebtedness from one year to another, more than to invest.

The institutionalized credit system is, then, unable to assist the bulk of the poor farmers, who have to rely on the usurious loans and/or to sell their products at any price to the local merchants.

It thus appears that we should think of the capitalist and the peasant farms as two completely different kinds of social and economic organizational units. Both the quantity and quality of their resources are distinct, as the result of their different relative power positions in the process of appropriation of these resources. In addition, each type of unit has its own criteria about the best way to exploit what it has.

The capitalist entrepreneur observes the market, gets the necessary inputs, combines them according to the technically most adequate proportions, and tries to maximize his investment to earn the highest profit possible.

On the other hand, the peasant family exploits its small plot, applying the best of its own labor to it, and usually consuming all or the greatest part of its product; its production is often not large enough to support the family all year, so the peasant thus resorts to the temporary sale of his labor force to complete his yearly income. In a word, we could say that the capitalist entrepreneur seeks a profit, while the peasant farmer just tries to subsist.

How can two enterprises of such a different kind and purpose coexist? How can they confront each other in the same market and receive the same price for their products, without the weakest one, the peasant farm, being destroyed and wiped out? To what does the peasant organization owe its historical permanence, and its ability to survive in such different social and political systems, in so many times and places?

The scholars generally rely on the great internal coherence and the relative economic autonomy of the peasant unit to explain its capacity to withstand heavy tributes or taxes, and to withdraw upon itself during the most violent periods. The story of the Mexican peasantry well illustrates this ability for survival, and also its limits.

The Spanish conquerors turned into their own the tribute system imposed by the Aztecs on their dominated neighbors. However, they exaggerated their spoilage to such an extent that the Indian population—and with it, the tributary system—collapsed. It has been estimated that the Indian population of Central Mexico numbered between 11 and 25 million in 1519, date of the Conquest, and was reduced to one million eighty years later.[2]

The Spanish then had to settle down as producers themselves, and they did it mainly—in the rural area—through the creation of the *Hacienda*.

The haciendas were rather versatile enterprises, with a peculiar mixture of feudal and mercantile features, which varied according to the region and to the fluctuations of the external and internal markets. The haciendas were created and expanded at the expense of the Indian communities. They did not take away the peasant product as did the tributary system, but directly expropriated the peasants' resources: their lands and their labor force. The haciendas partly used freely hired work, but the bulk of their manpower was the impoverished peasants, attached to the estate as "peones acasillados" (peasants legally tied to the haciendas, and obliged to work on them, in a very feudal manner) by means of hereditary debts.

On the eve of the 1910 Revolution, nearly half the peasant population of 6 to 10 million was under the haciendas' control; half a million maintained their lands and communal organization in the mountainous and isolated states of Southern and Central Mexico, such as Oaxaca, Morelos, Guerrero and Michoacán, while a similar number privately owned small plots or rented the neglected marginal lands of the haciendas, mainly in the states of Jalisco, Veracruz, Guanajuato and Mexico.

This geographic distribution of the socio-economic rural groups before the Revolution largely helps explain the present regional differences in the agrarian structure and the impact of the Agrarian Reform.

The Agrarian Reform was legally proclaimed in 1917, but virtually unobserved until the Cárdenas Presidency (1934–1940). After the great impulse he gave to land distribution, there were another twenty years of a nearly complete suspension of activity in this area, associated with a politics of costly public investments—particularly irrigation programs—

[2] W. Borah and Sh. Cook, 1962–63, p. 5.

which mainly favored the privately owned areas (the northern and northwestern states).

The growing peasant discontent obliged the last three presidents (1958–1976) to resume the distribution, and in 1970 (date of the last census) nearly 70 million ha had been distributed between 2 million peasant families, composing 22 000 ejidos. The *Ejido* refers to the common possession of an extension of land by a group of peasants who live in the same village. This land usually comes from the partitioning of an hacienda. As a rule, each *ejidatario* (ejido member) works by himself on his plot and has exclusive property on his product, although the lands of a few ejidos are collectively cultivated. The plots in the ejidos are usually small; most of them are not irrigated, and they are often hilly and eroded. Their average size in terms of "temporal" land is 4.8 ha, with 1 ha being naturally or artificially watered. These conditions, obviously, only allow for a peasant type agriculture.

As a matter of fact, it seems that the whole of agrarian politics in Mexico has, as its main purpose, to help stabilize a double structure in the rural areas, with its prosperous capitalist and its poor peasant sectors.

The capitalist enterprises specialize in the highly profitable products and exports. The peasant sector, on the other hand, first of all feeds and retains in the countryside a large population that industry could not employ; its production also contributes to the provision of the workers and poor urban population; finally, most peasants sell, for an extremely low wage, their labor force to the capitalist enterprises which need many workers in the peak periods of the agricultural cycle.

We must interpret the peasant sector situation both as an expression of the inner organizational principles of its production, and as an answer to the social and economic conditions that the capitalist system imposes on the peasants. As we mentioned above, the virtually self-enclosed character of the peasant production and consumption unit operates as an essential self-defense mechanism; but it also represents a serious weakness when its resources are limited, or when the unit is obliged—as in the capitalist system—to participate in the market.

The peasant family does not look for profit; that is what assures its continuing participation in the market despite the most unfavorable conditions it has to endure. But the same basic feature which explains the specific rationality of its production (i.e., the fact that the owner of the means of production is also the direct producer or, in other words, the loss of contradiction between Labor and Capital), determines also its inability to compete, and even, in many cases, subsist, in a capitalist-dominated environment.

Both their inner norms, and the imposed limitation of land and credit, drive the peasant farms to a technically inadequate use of their resources and to a low level of production. The market system (and specifically, the price mechanisms) impedes any internal accumulation of the surplus product (if any) and channels it out, towards the commercial and industrial sectors. Finally, when the peasant works as a temporary wage earner in some large agricultural farm or in the construction industry, the economic pressure he suffers, the large supply of labor offered, and the complement his own production provides to his maintenance, urge him to accept very low wages.

We may, thus, observe a peculiar and yet, in Mexico, common situation, in which the peasant, in a self-sustained process, employs himself, temporarily but recurrently, as a wage earner as the only means to avoid his complete proletarianization and to maintain his peasant status.

This last mechanism would constitute, together with the partial expropriation of the peasant resources and the relative "devaluation" that the market system imposes on his product, the main economic channels by which peasant agriculture contributes to capitalist accumulation in Mexico.

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DISCUSSION

Haluk Kasnakoglu (Ankara, Turkey). You paint a very dark picture and it's a dark picture because there are no apparent overt conflicts in the system in your representation which will force the system to force its boundaries toward new structures. It's a very stable system and I think your last comments about the polarization of the masses, the agricultural masses, is indicative of your line of approach. I will debate that, mainly because I disagree with your starting point. You claim that the basic criteria of comparison between the capitalist farmers and the small farmers should not be one that is based on efficiency but one that is based on the availability of resources. I completely disagree with you—it should be based on efficiency. I will explain with a couple of comments where you contradicted these statements. Let me say initially that I really have great faith in the farmer, small or large, the complexity of their operations, and the matter-of-fact way in which they go about performing these operations is the basis of my belief. You said, for example,

that the small farmers used their land resources quite well but they used their labor badly. At the same time you said that they used family labor intensively. Now, this is a simple matter because it is the factor proportions that are available to them, so I don't think you are consistent in making these two statements simultaneously. Maybe it would be better if we defined what efficiency is. Efficiency is making the best with what you have and I'm sure both the capitalist farmers and the small farmers are making the best of what they have. It is a basis for survival. However, the problem is this: What will happen if this system is disturbed?—like what is happening in Mexico with the technological developments coming in? Can we project that the small farmer, who in my opinion is an efficient and a rational producer, will be able to adjust without great conflicts, without great competition with the large farms to a new system which allows him to produce more? In other words, if factors become available in your frame of reference do you think the small farmer will succeed in increasing his level of welfare, or will there be a conflict situation?

Martinez. Well, I think there are two basic features which could determine the economic behavior of the peasant farmer. The first may be the shortage of resources, I mean land and credit, not labor force, and the other is the organization of the peasant farm and its purpose when it is producing. You said both kinds of enterprises, the capitalist and the peasant one, are looking for survival. I don't think the capitalist entrepreneur is looking for survival—he's looking for profit.

Kasnakoglu. Which is necessary for survival.

Martinez. Well, not exactly. The capitalist entrepreneur could be a farmer and cultivate, himself, the land and he would survive, maybe, rather badly, but he would survive.

Kasnakoglu. I'm not talking about survival of individuals, I'm talking about the survival of institutions.

Martinez. Then if you were talking about the use of labor force it's an intensive use in the peasant organization and I said it was technically inadequate because of the very low remuneration the peasant gets for his work. It's not, of course, labor forces available to the peasant farm but it has a cost, maybe not a monetary one, but the peasant has to live and his family too, and if he employs too much work on his plot, he will get a very low remuneration for his work. That's why I said it was too intensive for the comparison with the size of the plot he has. We were talking about efficiency also. In the use of land it doesn't seem that capitalistic enterprises are more efficient than peasant ones. On the contrary, some figures which have been calculated by the Center of Agrarian Investigation in Mexico showed that the use of lands is much more efficient in the peasant areas than in the capitalistic ones.

Kasnakoglu. When you talk about efficiency you have to talk about the totality of operations and not individual inferences—their combination inferences. What about your projection?

Martinez. About the general situation, we have to take another dimension which would be the social, political dimension. In Mexico there is a very large peasant population, and a national population which is growing very fast and there is no more land to distribute. Even now, there is a shortage of land.

In the country, as a whole, there is a great deal of unemployment and I don't know what the peasant could do if he didn't stay on his land and try to cultivate it; there is a lot of migration, but they go to the city and they don't have work and it's not a very good situation. That's why I draw a very pessimistic picture.

Alex Tanis (Haiti). One of the gentlemen asked: Do the farmers want some change? I will answer in a very positive way. I will say they really need a change, but speaking from my own experience, I would say maybe not in an occidental style, because we in the developing countries are dealing with peasants who have no education and I think that this is the reason why most of these international agricultural improvement programs, most of the time, probably fail—because they have ignored one of the basic principles of extension. You must start from what the people have and improve this situation just step by step. But most of the time reformers want only to apply very advanced and very sophisticated techniques, and this hurts not only the feelings of the peasant but his social and economic way of thinking and acting. I would add, also, that even the governments of these developing countries want to change but we have to take into consideration that the future of the land in developing countries is in the mountains. So, the governments of these countries are faced with a very huge and complex problem. And taking into consideration the lack of means to achieve performance, they prefer to concentrate their resources on low land which is easier to improve.

We must first gain the peasants' confidence and also we have to insure their active and efficient participation in the process of developing, otherwise it is a waste of time and money.

In high land, in most of the developing countries, they grew only export crops such as cocoa, coffee, and pineapple and we know that the marketing of these commodities escapes the government and farmers themselves because it depends upon the price in the international markets. So I think we are dealing in a vicious circle. So as far as I put this principle, the marketing of these commodities

depends on international prices and market. I would like to have comment on this.

Martinez. In Mexico a lot of peasants work to produce coffee and sugar cane. But the sugar factories are in the hands of the government so the peasants in that case have no marketing problem because they are obliged to sell to the government factories. For the coffee, now there is a central institute which buys the larger part of the production and the international price problem is only reflected on the peasant production and the peasant income by the sale of that product. They have no influence over those prices. In the cotton and tomato and onion exports, the other three main export products, it's mainly capitalistic enterprises which produce them. They are the type that we offer to large American enterprises which sell fertilizer, seeds, and technology, whatever they need, and they are obliged to sell, for instance, to Anderson-Clayton, a very well-known enterprise in Mexico, and the producers have to sell their production to these enterprises. In that case, it's multinational enterprises which are in charge of the commericalization and of course it has very good profit. When the producer is big enough he gets a very good profit with his production, too, and the bigger agricultural capitalist enterprises in the north and northwestern states in Mexico are flourishing, but there is a part of their profit which goes to the multinational and every kind of marketing enterprise which is not in the peasants' hands.

19.
Sociocultural and Agricultural Organization in Hill Lands in Kenya

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In this conference we are considering four factors influencing agriculture on hill lands: the physical characteristics of earth and sky, the technology applied to these, the economics of the interactions between the two, and the sociocultural systems that both derive from and shape individual and group decisions on technological choices and economic goals.

I will discuss the evolution of agricultural systems among a hill people in Kenya, as if you were a stranger planning to work in the area. I will stress the interrelations between social and cultural structures and agricultural systems rather than establish connections between a few isolated customs and selected agricultural practices. I could tell you that the Imenti of Kenya prefer that a banana plantation be cultivated for at least 50 years before it is replaced by new plantings, because it represents stability of family line from grandfather to grandson. But you, as a non-Imenti interested in working with Imenti agriculturalists to improve their long-term yields, should find it more useful to learn that this specific custom is part of a wider community-enforced concern with groundcover as well as part of the cultural definition of a household. A cultural structure is a general principle of human behavior which is widely accepted within a group. Knowing the structures behind specific practices, we are able to estimate what is most susceptible to change.

A structure is not unchanging, any more than is a single custom, although it is less likely to change without warning. The Imenti concept of the household (of which the permanent banana grove is a symbol) is changing to adapt to new settlement patterns forced by increasing population and government edict. Knowing the goals behind this concept and the resources available now and in future years to achieve them, one can guess at the ways in which the concept of a household will be expressed in the next generation. But in changing that structure and the available resources that generation will learn a somewhat altered set of goals, and therefore prediction of a structure two generations hence is risky.

Another facet of cultural systems to remember is that different groups of people choose different aspects of behavior and attitudes on which to impose structures. The Imenti regulate the care and use of trees, but they have left the deepest religious matters up to the individual. We Americans have regulated the provision of a weekend, the same one or two rest days per week for almost everyone, to reinforce

(Note: This research, but not the analysis, was conducted prior to my affiliation with the Rockefeller Foundation, under a NIMH/NIGMS grant.)

family and friendship ties, although it is economically disadvantageous; but we leave most energy conservation decisions to the individual consumer.

The 80 000 people of South Imenti Division,[1] with the approximately 120 000 people of North Imenti Division, represent the core area of Meru District and of the Meru tribe, one of the largest ethnic groupings in Kenya. The Imenti live on the lower slopes of Mount Kenya, which rises 5 200 m above sea level, between the altitudes of 900 m and 2 200 m. Their farms replace natural vegetation that varied from moist montane forest above through moist and dry intermediate forest to savannah woodland below. They are bordered on the plains below by a related group of Meru. They grow tea, coffee, tobacco, cotton, sugarcane, wattle (a tree from whose bark tannin is extracted) and, recently, pyrethrum for sale; and maize, millet, a wide variety of bananas and legumes, and many lesser crops for sale and home consumption. They live on dispersed farms averaging two ha of land per family, the average family consisting of 8.4 persons, of whom 4.3 are fifteen years or younger. There are few non-Meru, and even non-Imenti, present in the Division. Imenti farmers engage in continuous cultivation or short-term fallow depending on the altitude and soil type, rarely possess an agricultural tool more complex than the hoe (which is itself fairly recent), yet use irrigation and terracing and have almost universally adopted the use of fertilizer and insecticide on staple crops. Their cattle, goats, and sheep graze on the roadsides and in fallow and public fields. Where grazing has become insufficient the owners bring tree branches and grass to the livestock. Great care is taken to keep the area heavily wooded.

The traditional administrative and political boundaries of the Imenti, accepted by the British colonial authorities, have been steep river valleys. The Imenti, with the other Meru, only came to Mount Kenya some 250 years ago, trekking several hundred miles inland from the coast over a period of several generations (Fadiman, 1970). They were part of a vast and slow migration of peoples that had started from West Africa at least 1 500 years ago, and had taken up the cultivation of bananas so that they could survive in the tropical rain forest of the Congo. The Imenti were the last segment of a group that had moved from the Congo to Tanzania and Kenya. They settled on Mount Kenya's eastern slopes at about 1 500 m altitude, where the temperatures and rainfall were agreeable, soil fertility high, and mosquitoes and tsetse flies relatively absent.

As population increased, the Imenti began to herd their livestock in the colder area above the homestead zone, and to plant annual crops such as millet and beans above and below this zone. Food was thus produced up and down the mountain slopes and brought to the central zone for consumption. Because the river valleys were so deep, and often impassable at homestead level during the rains, families established between a pair of rivers were set apart as a single political and economic unit. The colonial government recognized these divisions and more or less followed them in creating the administrative units that persist today.

In the 1950's, however, just prior to Kenyan independence, the government began a land reform process in the District which profoundly altered the economic structure underlying these units. In accordance with the British model of good husbandry, the government assigned land titles to all adult males then farming, and consolidated all of a family's plots of land into one contiguous holding. Where before an old man, his sons and their wives had cultivated several plots in each of the three zones and brought the produce back for joint consumption, now each couple was given a single, larger plot in one zone. This process was begun in the northwest of the Division in 1962 and was just being completed when I left in 1972. Lands were allocated on the basis of present farming use and probable needs of mature sons, judgments being made by councils of representative elders in each subunit and subject to appeal. The process was quite fair, judging by the present distribution of land among village leaders and ordinary citizens, but tended to penalize young families just beginning to cultivate and subunits which were already overcrowded.

Although theoretically a family could have remained together, the sons relocated in separate zones knew that legally they no longer had a right to claim produce from each others' lands or to assume that they would be allowed to continue to live at the original homestead. It was safer to establish their own homesteads and to try to develop something approaching self-sufficiency within a single zone. It is probable that this situation would eventually have come to pass anyway, as increasing population and family splits were already forcing some pioneers to try to establish homesteads farther up the mountain slope. These pressures may have provided a reason why the Imenti did not oppose the reform as strongly as did their neighbors on the mountain. But the reform did hasten the process, not only because of the legal fiat but also because the British and later Kenyan governments felt obliged to help the settlers in new zones adapt to their environments. The malarial mosquito in the lowlands was substan-

[1]This was in 1971; probably they are 90 000 today. I am using "Imenti" to describe three very closely related groups that are likely to continue to grow closer together rather than farther apart. Over two-thirds of both divisions are "real" Imenti, i.e., belong to that older political grouping. A Division is the Kenyan administrative unit below a District and is roughly analogous to a county.

TABLE 1. Agro-economic differences between the zones in 1971–72[a]

Item	Upper Zone	Middle Zone	Lower Zone
Population densities:[b]			
Median ha farmed or owned	2.4	1.6	2.8
Mean ha farmed or owned	3.4	2.4	4.2
Median household members per ha	2 ½	3 ½	1 ¼
Cattle:			
Local stock:			
% households owning one or more	69	63	40
of these, mean number owned	2.4	2.5	4.0
Improved stock:[c]			
% households owning one or more	53	23	3
of these, mean number owned	3.1	1.9	1.6
Non-crop earnings:			
% households with any such	67	51	39
% households with one or more regular, well-paying job	31	30	24
Housing:			
% households owning metal roof	35	44	16
% households owning metal, stone, or wooden-walled home	16	5	1
Crop sales:			
% households selling			
tea	71	8	0
coffee	58	91	57
tobacco	0	37	59
cotton	0	0	21
maize	42	59	78
bush beans[d]	22	50	80
millet	1	7	31
cow peas[e]	1	8	18
bananas	5	27	14
yams	7	16	7
potatoes	23	14	10
cabbage	27	6	2
Mean food crops reported sold	1.4	2.0	2.9
Foodcrop purchases:			
% households buying			
maize	90	85	75
bush beans	74	68	59
millet	16	28	29
Foodcrop purchases:			
% households buying			
cow peas	22	21	12
bananas	34	13	22
yams	17	7	9
potatoes	46	28	25
cabbages	8	1	12
Avg. net cash income (US $)[f]	485	298	144

[a]These data based on questionnaires from 540 farm households in 18 localities.

[b]These figures have been translated into hectares but were collected in, and rounded to, local measurement units (acres).

[c]"Improved" stock are a cross between the local zebu and British stock which have been adapted over several generations to Kenyan conditions. They provide three to five times more milk than the zebu and have almost as good disease resistance.

[d]"mung'au" = *Phaseolus vulgaris*

[e]"nthoroko" = *Vigna uginculata*

[f]After agricultural and other production costs paid or redeemed in cash were deducted.

tially reduced, aid was given in clearing fields and roads, and crops cultivable in the cold uplands were identified and promoted.

The results of the reformers' simple decision to consolidate lands were a new family structure, new crops and cropping systems, a more active marketing system and much greater individual insecurity. Previously sons had remained at home as farmers and built their homesteads close by as their own children matured. Now many had to leave home. Parents compared the numbers of their hectares with those of their immature sons and began to plot ways to put excess children through school in the hope that they could later find jobs. Landless educated sons planned to find jobs to earn enough money to come back and buy land for themselves. Family planning, introduced seriously only after my departure, has reportedly caught on like wildfire (Greeley, 1976).

The upper zone has changed the most radically. Although farmers try to maintain maize and bananas there, these crops do not do well and the main staple is shifting to white potatoes. Cabbages also grow very well, and both of these foods have begun to be eaten by families in other zones as well. Although much of the upper part of the area was cleared by the British for military reasons during the war for independence, once cleared it was immediately invaded by bracken fern, a long-rooted weed requiring much labor to extract. Most larger homesteaders have put part of the land into trees producing wattle and firewood, and have abandoned up to a half of the remainder to fallow until they have enough grown sons to help clear it. Upper zone households have to spend the largest amounts on food (especially maize, bananas, and beans), but they can afford to do so because the produce of their zone, particularly tea and milk, is now the most profitable in the region. These two products are each supervised and marketed by a special society. Most tea inputs are obtained on credit, and even a poor farmer with a half-hectare of land in tea can achieve sufficient income from the crop to provide for a family of eight. Better-off farmers that look good credit risks can get loans to expand dairy operations and buy improved stock, and because there is less risk of disease and more open land than in the middle zone, herds are larger, healthier, better-fed and more productive than elsewhere. Tea and milk accounted for 42% and 37% respectively of gross cash income from farm activities in three sample households (Almy, 1972) from this zone; the fourth was a young entrepreneurial couple

engaged in a wide variety of short-term enterprises while they began a tea plantation. Tea probably would not have become a major crop without the relocation of households, because it requires the daily year-round attention of at least one person (for a small plot). Potatoes and cabbages almost certainly would not have become staple foods without the perceived need by the relocated households to supply as much of their own subsistence as possible. At present this zone is very well off, but its prosperity rests almost entirely on the prices of tea and milk, both fixed by the government, and were these to plummet, the area would be in deep trouble. However, because the climate is relatively temperate, many well-researched possibilities exist for cash crops. In the year I arrived, pyrethrum was introduced into the area, and the demand for seedlings soon exceeded the supply.

The middle zone has modified its own productive system as population has been drawn off to the other zones, eliminating both internal family sources of food from those zones and labor needs for them. Maize and coffee areas had been expanding for decades but seem to have been stimulated to a further, and final, expansion by the change in land tenure, at the partial expense of banana and yam groves. Coffee provided 53% of gross cash income from farm activities in four sample households, with households from different microregions specializing also in tea, tobacco, beef cattle and yams. Most households in this zone are reducing their herds to one or two cows, now that their access to free forage has decreased. Food expenditures are absolutely lower than in the upper zone but relative to income remain the same. The middle zone is also currently middling in cash incomes, and has experienced a drop in cash income over recent years as the price received for coffee has declined. They have not yet adapted to this decline, and many people were still spending very close to their incomes, in the years I was there, on a variety of non-vital consumer luxuries (better clothing, meat, better housing). Except for this problem of reducing living style expectations to current incomes, middle-zone households do not have to deal with the possibility of a sudden decline in demand or price for their most important products, unless the government takes the unheard-of step of ending its coffee program. Most of the other products sold from this zone are marketed through channels and have stable levels of supply and demand.

The lower-zone households have established new banana groves where previously there was little but annual crops and fallow. The farmers have brought coffee as far down the mountain slope as it can possibly grow, confounding government dicta of feasibility in the process. Tobacco is also being planted farther down the slopes than previously, and probably in greater quantities than before because of the greater need for a lower-zone cash crop. The government does not recognize tobacco as it is grown in Meru as a cash crop, as it is not of cigar or cigarette quality. Trying to find a cash crop for the zone, authorities have used a mixture of coercion and promotion to introduce cotton. Cotton requires a heavy investment of both materials and labor to produce an adequate return, and there is no institution similar to the tea or coffee societies to assist with credit and supervision, so cotton is limited to a single area at present. This area has a localized farmers' society which was set up to assist the settlers in land clearance, irrigation and roads, and which now provides tractor service and marketing assistance to cotton growers. In 1972, local agricultural agents were considering how to provide services to cotton farmers outside this area within the twin constraints of lower homestead densities and lower cotton prices.

Most farmers in the lower zone rely on a combination of food crops and a little coffee and tobacco. Among the four sample households in this zone, coffee provided 33% of total cash income, tobacco 19%, and bush beans and cotton 17% each. Farmers sell small amounts of the full variety of traditional foodstuffs in the markets farther up the mountain and grow enough to avoid having to purchase. Households in this zone can assure themselves of subsistence most of the time regardless of market forces, but, with current technology, cannot obtain enough cash to purchase the improved housing, education, and other luxuries that make life easier and healthier for their upland cousins. The lower zone is also low enough in rainfall to be somewhat susceptible to the periodic droughts. To avert this problem, the British required the planting of cassava as a reserve crop. The Imenti don't like cassava as a food, and most lower zone farmers depend on securing enough rain to raise millet instead. In normal years some of this is eaten and some marketed in the lower, drier plains where the people have not had the opportunity to acquire a taste for maize or bananas as staple foods.

Behind these detailed descriptions of changing agricultural systems in three zones lie four continuing goals of the Imenti farmers: first, to provide for basic food supplies within the household; second, once this is achieved, to locate a combination of crops that will bring in enough cash to educate the children and pay for increasingly luxurious forms of food, shelter, and clothing; third, to keep at least half the cultivated land in permanent or perennial crops; and fourth, to maintain livestock if at all possible. The first, third, and fourth objectives are related to the traditional division of authority and status between the sexes. The woman of the household has been responsible for annual crops and the

feeding of the family; the man for the permanent and most perennial crops and the livestock. Woman's status is tied to her ability as a family provider; man's to his abilities to contribute sugar cane beer (involving a yeasty fruit of the *murantina* tree) and meat to the men's organizations and to provide the stable core of the household's food from the banana/yam grove during drought. New crops have been assigned in the same manner. Although these roles are becoming much less defined, the major authority and status for each crop type remain with a single sex. Abandoning either part of the farm enterprise would be unthinkable. Examination of farms managed by widows and grass widows (with husbands employed elsewhere or deserted) shows that the two systems are maintained with the help of sons or in-laws in order to preserve the households intact for the couples who will inherit.

Changes in the economic, and probably the political structures of the region are following the changes in agricultural organization. The first regional economic effect must have been an increase in the volume of produce passing through the local markets, as people from one zone came to sell its produce and buy foods they could no longer grow in sufficient quantity. The supply of cash and ability to buy externally produced goods, such as radios and fertilizer, have generally been enhanced by the zonal specialization, but families moved to the lower zone now probably have less access to cash than they would have as units of more crowded middle-zone homesteads. The measurement and legalization of each man's land has also been a major impetus towards the movement of landless young men out of farming into employment in government offices, shops and services, and towards major community and family sacrifices to build schools and maintain their children in them. Most youths expect to earn the money to return to farming, but many will doubtless be unable to do so, and will bring forth the first generation of town dwellers: landless laborers, service personnel, and marginal craftsmen (Table 2). This trend would be greatly retarded if the government research stations turned greater attention to maize, potato, and bush bean yields in the upper two zones and to the improvement of tobacco, cotton, or a new cash crop in the lower zone. But this is unlikely because these crops are not important to the gross national product nor are the Imenti farmers as needy as many of their compatriots.

A single change in the current agricultural organizations to bring them fully into line with the traditional and current non-agricultural structure would go far towards achieving a partial solution to the problem of land pressure through local financing of agricultural support structures and non-farm job creation. Local government was and is based on councils of older men who judge cases, determine policy, and negotiate where necessary with spokespeople of younger men's and women's groups. Locality councils select members to represent them at the next higher levels, producing a chain of policy councils extending to District level,[2] although non-local administrators are chosen by the government and many laws are imposed from the national level.

Locality councils once had the power to discuss and veto the fallowing of land in the homestead zone, to change the allocation of land to heirs and non-local supplicants, and to veto the cutting of any tree or require the planting of a new one in its place. The Coffee Society (a cooperative) took over some of these functions for coffee only in recent decades, training local youths to supervise all phases of cultivation and planting, and providing marketing, preliminary processing and credit for inputs. The Society's structure is an adaptation of the traditional council. In its early period it was composed largely of younger farmers, and so the traditional age structure has declined in importance. The Society is locally controlled, and during the fifteen-year period in which it has represented most households in South Imenti its membership meetings have resulted in most of the economically oriented group decisions made in the Division. The need for jobs for the landless and land-poor has been met by mounting administrative costs as the meetings agreed to expand paid processing, extension and managerial jobs in coffee. The concern for foodcrop yields on shrinking farms has been met by a decision to sell, and advance credit for, maize and potato fertilizers and insecticides, hybrid maize seeds and general-purpose farm tools, despite the fact that the Society cannot buy anything except coffee. Because of this marketing limitation, a household has to plant coffee in order to obtain the benefits of membership, and many people live too high or low on the mountain or could make a better profit from the same investment in tea.

The Tea Society, although introduced and still controlled from the national level, follows the model of the Coffee Society. It provides close supervision of all phases of tea cultivation by local youths, processing in a locally built factory, marketing at a fixed price with a guaranteed lower limit and credit for inputs. Because the operation is controlled by a parastatal firm in Nairobi, it does not reflect the wider economic and agricultural concerns of the upper-zone farmers. But by 1980, according to the

[2]This is a rather simplified view: since the British left, these councils have lost place to others elected democratically by the entire adult population; it was difficult for a woman to learn much about them at upper council levels, but it appeared that they only continued to meet at the locality level and, as a kind of honor society of ancients, at the District one while I was resident.

TABLE 2. Calculations on potential land availability for the next generation[a]

Probable Status	Upper Zone	Middle Zone	Lower Zone
Household leaves land (now owns under two thirds area needed to subsist)	10%	8%	25%
Present hectarage (converted from acres)	to .6	to .6	to 1.2
Household continues 1 son on land	27%	32%	24%
Present hectarage	.7–1.8	.7–1.3	1.3–3.0
Household continues 2 sons on land	15%	23%	12%
Present hectarage	1.9–2.7	1.4–1.9	3.1–4.6
Household can continue 3 or more sons	48%	37%	39%
Present hectarage	over 2.7	over 1.9	over 4.6
% population that would be able to stay on land if zone redistributed land equally in subsistence plots to all.	200	120	100

[a]With birth control, the next generation will have to maintain as one household one aged parent (the second surviving but cared for, either physically or through payment, by the other son), a couple, and their four children (six being anticipated but with a short time period during which all are at home and/or alive). The present generation of farm owners has an average of 2.6 sons, which has been taken as the number the present house owned will have to accommodate by the time the retiring owner's sons have reached the life stage in which he is presently. (This, as the rest, is a wild approximation; some of the current sons are grown and received land in the reform or since, and the younger fathers are just beginning to bear children.)

From the twelve economic interviews (Almy 1972), particularly those in which family size is straining resources, I have estimated the lowest farm size at which a family of ten (the present average for a complete family) can feed itself and obtain the cash to pay taxes and school fees, and minimal food, clothing and other bills. The only changes in relative prices anticipated here are 50% higher cotton returns once the agricultural agents get the bugs ironed out of their extension and marketing system.

Upper zone: 0.2 ha tea, 0.2 ha pasture (for milch cows), 0.8 ha maize/potatoes/mixed foods = 1.2 ha for a family of ten + 0.1 ha homestead = 1.0 ha for a family of seven.

Middle Zone: 0.3 ha coffee, 0.4 ha beans/maize, 0.2 ha bananas/mixed = 0.9 ha for a family of ten + homestead = 0.8 ha for a family of seven.

Lower zone: 0.1 ha coffee, 0.2 ha tobacco, 0.4 ha cotton, 1.1 ha maize/beans, 0.4 ha bananas/mixed = 2.2 ha for a family of ten + homestead = 1.7 ha for a family of seven.

Incidentally, the land reform planners felt that 2.4 ha were necessary for subsistence in the middle zone and 4 in each of the other two. This was achieved as an average in the middle and lower zones for this generation, and under achieved by 0.6 ha in the upper.

government agreement with the parastatal firm, the Tea Society will have been transferred completely to local ownership by the producers. At that time the number of jobs created by the Society will rise, profits will drop slightly and credit and provision of other inputs not related to tea will appear.

If these organizations were encouraged by changes in the national cooperative and commodity control laws to convert fully to multipurpose societies, the prospects for a locally generated spurt in employment and crop yields would be good. Unlike many other peoples in Kenya and around the world, the Imenti have had long experience in the community supervision of agricultural decisions, and if a structure is not imposed granting extraordinary powers to a single individual or authority to a stranger, they should have little trouble in running and improving a multipurpose structure. Undoubtedly they would produce more foodstuffs relative to non-food cashcrops (coffee, tea, cotton) than the national planners would prefer if present technical and marketing constraints on foodcrops were eased, but the alternative would probably be for them to convert further to cashcrops and begin to import food, straining the more limited food supplies elsewhere in Kenya. Multipurpose cooperatives would also open the way for employment in local food-processing plants. Such plants have been discussed by Meru public and agricultural leaders for years but presently cannot be implemented except through the creation of a new government parastatal firm. To date, coffee, tea, maize, and a few crops can only be sold to cooperatives or parastatal firms designed to handle a single crop.

I have tried to describe the history and present status of the agricultural systems of the people of South Imenti, how these affected and were affected by the sociocultural structures of the region, and what will be the region's likely and possible alternative futures. Many regions are not as fortunate, either ecologically and economically or socially. The Imenti do not provide an answer to the problem of how to develop an economically backward and socially disrupted agrarian society to the level which the Imenti have presently reached. But if they are blocked from above in developing the community institutions necessary to carry the region over the next major structural economic change, we may be

able to study its decline. I hope that they will not finally provide such an example of what not to do. It is cheaper to adapt and build on a local successfully functioning system of agricultural organization than to impose a structure from the national level. Further, it is easier to assist an intact economic and social system to revise its agricultural priorities and methods to cope with future threat than it is to try to rescue that system once it has fallen apart.

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DISCUSSION

Mercer (Great Britain). Your description paints a very optimistic picture, really, of an area which is developed, and you're concentrating very much on the social changes, the social patterns which were evolved. I think perhaps you have underplayed the part that has been played in the process by the availability of research in the situation of Kenya which was available to transmit in that area. You perhaps also underplayed the role of the institutions available in Kenya. For example, the coffee institution, the milk marketing board, the Pyrethum Marketing Board, the Kenya Tea Development Authority, all were able to channel information back to the cooperatives you're talking about and have allowed the continuation of high quality goods which compete in the world market. I wondered what your views are in the comprehensive view of development of those particular aspects?

There is a danger of moving too quickly from single-purpose cooperatives where quality is important to the multipurpose one where you diversify too quickly and lose the main idea of the crop which this particular area depends upon for survival.

Almy. I would agree with most of that. The Kenyan government has been a lot better than some of the governments in Latin America, for instance, in helping the small-farm areas. But the Coffee Society, which is the oldest cooperative in Meru, is the most successful coffee cooperative in Kenya—in fact, probably the only truly successful coffee cooperative. The others kind of limp along. Recently economists looking at the Meru have said that it is in trouble, too, because it is spending a lot of money on administrative costs, but these costs are a direct response to the local needs. One of the reasons that it is successful is that during the period when it was introduced on the district level to all of Meru, the colonial officer who was in charge of that district was very knowledgeable and sympathetic to the local institutions. The Coffee Society was developed in such a way that it meshed with those institutions and mediated for them with the national government. The government has not done as good a job elsewhere.

I would very much like to get back and look at the history of the Kenya Tea Development Authority because in some ways it seems to me that it has been picking up from the Coffee Society model. I don't know whether the Tea Authority is an independent invention or not, but it is declared by a number of transient experts as one of the most successful agricultural support structures for small farmers that they have seen. I would agree that the Kenya government has been much more benevolent than it could have been. I realize there is a danger in over-diversification. I have tried to point out that they have already been diversifying on the input side as much as they could. In a lot of cases where you bring in a multipurpose cooperative, it's in an area where people haven't been used to cooperating together. In an area where this has been an important activity for some time and the cooperative structure is intact, diversification has a good chance of succeeding.

Kevin O'Connor (New Zealand). May I ask you to please comment on your conclusion, which, as I recall, was that an ounce of prevention was worth more than a ton of cure. You described the situation before the land consolidation as one in which people utilized their land in the three zones integrated around homesteads in the central altitudinal zone. Now, supposing you were counselor to a government or a local regional authority before this stabilization

in separate zones was to occur, what do you think would be the way in which you would counsel? Would you recommend that the hill people need to have bottom zone, top zone, and central zone utilization patterns? Or do you believe that some change from that very complex system was necessary in order that any other change could take place?

Almy. If I had been there in 1958 I probably would have recommended that they continue the patterns that they had. For legalization of individual land titles, I think now that would have been a mistake. I didn't personally think very much in terms of mounting population pressures in that area at the time. Although I knew landless youths that were very worried about land access, I agreed with their idea that they could go away, earn some money and come back to buy land. But now that I have done the calculations I realize that there's not very much land to buy. The legalization of titles forced people to think hard about where else to find jobs, and about what the local communities could build in the local area that they could control and employ people in when they couldn't stay on the farms any more. I think that was very important.

On the question of consolidation of holdings, if they had kept the land allocation so that a farmer had a little land in every zone, I personally think that that would have been better. It would have made the homestead zone very crowded after a while, and it might have blunted the pressure to get people off the land into schools and then into clerical jobs and the like. But the consolidation makes them dependent on market forces much more than they were before. They were already participating in the market, but they weren't dependent upon it for subsistence, and now a substantial minority is so dependent. They don't trust the market much, and I don't trust it either. But in the long run maybe its positive effects on the local non-agricultural sector will make up for its negative effects on agricultural security.

20.
Changes in Rural Social Organizations as They Relate to Hill Farming: A Comparison Between Rural Mountainous Appalachian and Greek Communities

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In comparison with past centuries mountain rural communities and hill farming have undergone unprecedented changes in the last few decades. In some societies such changes are still taking place and in some they will occur in the future. These drastic changes are caused by the technological advances of the last few decades which had a unique impact on hill farming, major rural social institutions, and eventually the personality of the mountaineer. As compared with communities in the plains, the impact of technology in the mountains has been in many respects much more drastic. These changes follow distinct patterns. The concern of this paper is the basic social and socio-psychological aspects of these patterns. Although these aspects are examined in relation to only two mountain cultures (the Appalachian region of the United States, a country of high technological development, and mountainous Greece, which in certain respects could be considered of intermediate development), we speculate that they are universal.

Until a few decades ago, even in the most industrialized societies, mountainous rural communities functioned as cohesive and relatively independent social systems. This is still true in several developing societies. In other words, although they were parts of the larger society, isolated mountain communities usually had autonomous lifestyles and ways of doing things. Furthermore, their members usually found these lifestyles and the social organization that supported them meaningful and in many respects satisfying. As we will see later, this satisfaction kept the Appalachian farmer in the mountains a little too long, and as a consequence, there evolved considerable distance between his lifestyle and the more widely accepted lifestyle of the larger society. This distance, together with increased pressures from the larger society, created severe occupational and often psychological discords.

Prior to World War II, solidarity within the community was high and the major groups that individuals compared themselves with were primarily

within the community. For instance, concerning one's income and standard of living, comparisons were not made so much with outsiders as with people within the community. This local solidarity was supported by the institutions of family and religion.

In both societies, at least in the past, family life was cemented through everyday activities on the subsistence farm and was supported by a corresponding value orientation which favored this kind of life. Value of familism, of rural life, and of attachment to the land were predispositions of this kind. Moral values which were, in large part, of a religious nature provided support to the value orientation of the villager.

Despite cultural variations between rural Appalachia and mountainous Greece, the family functioned in both regions as a tight-knit social and economic unit. All family members worked on the farm, where the division of labor (concerning the role of the father, for instance) reflected the division of social roles within the family. This division included a well-defined status and authority pattern where the father occupied a privileged position. Both division of labor and authority patterns were meaningful to young and old, who had been socialized within a relatively closed system of relationships. As a consequence, they developed personal values and attitudes corresponding with those of the system.

Reality, which as we will see changed drastically within a short time, was perceived on the basis of this system of beliefs, values and social structure. A large part of this structure was the product of repeated interaction patterns initiated by socioeconomic activities within the farmstead. For instance, rural Appalachians, at least in the years prior to World War II, perceived realities about rural life and hill farming in a way which told them that the good life was in the rural community. The majority of them did not out-migrate, despite the fact that they knew they could secure better jobs in the industrial centers surrounding the region. Technically we call such attitudes "boundary maintenance mechanisms." In line with these attitudes, farming was considered by many to be of higher status than an industrial job. The following represents a fairly typical response, given during a brief survey conducted in Boone County, West Virginia: ". . . I knew I could make more money in Detroit but I felt I had a good life right here, and also I didn't want to lower myself working for someone else. But my son and grandson took those jobs and they were glad they did."[1] To an extent a similar situation existed in mountainous Greece before the sixties.[2]

In general, one might say there was a relative accord or equilibrium between the personalities of the villagers (part of which is their value orientation), the social system (for instance the rural community, family, etc.) and the third major part of society, the culture system, which includes among other things the farmers' occupation.[3] In rural Appalachia before the forties and in mountainous Greece before the sixties, new technological developments were not extensive enough noticeably to upset this equilibrium. As a consequence we say that there was a relative equilibrium among the three major societal systems which is often associated with satisfaction with existing lifestyles. Hill farming played a stabilizing and important function in maintaining this equilibrium.

But drastic technological changes occurred and accelerated during the 1930's and 1940's (about fifteen years later and less extensively in Greece) which created conditions upsetting this equilibrium and at the same time absolutely changing the nature of hill farming in both societies.[4]

The purpose of this paper is to describe, compare, and explain patterns of rural social change that follow these technological changes, in particular as they relate to hill farming. More specifically we will deal with the following: first, the breaking up of the rural mountainous community and of some of its major social institutions as brought about by these technological changes; second, the subsequent reorganization of the community and its institutions; and third, some of the more recent social trends in the rural and specifically Appalachian community, and how such trends can provide a blueprint for changes that will follow elsewhere.

As a guideline, before we begin our analysis, some generalizations may be presented about rural to urban transition drawn from the analysis that follows:

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[1]In the majority of cases the responses referred to one or the other of these two reasons for not receiving a job in the city.

[2]There was the understanding among peasants of the mountainous regions in Greece, that if you were to count all of the hours that the peasant and his family spent on the farm, the reward would be only a fraction of the wages the urbanites received for similar types of work. As in Appalachia, work of the whole family on the farm, although often involving considerable hardship, was often an end in itself. For instance, in the tobacco-producing region of Stavroupolis in northern Greece, women looked forward to the time when the small leaf Turkish tobacco had to be processed, which involved long hours of hard work. A large part of the activity involved opportunities for chatting with neighbors and friends who came to help with the processing.

[3]Defined in simple terms, the culture system includes all the things we do, think about, and possess, including technology.

[4]For rural Appalachia, these changes included automobiles, hard-surface roads, radio, TV, high schools and more jobs in the city. For Greece, the changes included most of the above with the exception of the automobile, but mass transportation and hard-surface roads increased considerably, as did jobs in the cities.

First—Despite considerable differences in time of occurrence and specific social forms, basic patterns of social transition are remarkably similar in the two societies.

Second—The major direction of change in social organization in both Appalachia and mountainous Greece has been toward the integration of rural populations into the larger society.

Third—The major axis of reorganization and in turn integration of the mountainous rural community into the larger society has been the economic sector (which includes hill farming and associated attitudes), supported by changes in other major social institutions (e.g., family, government, education).

Fourth—This new reorganization, within an exceptionally brief period of time, made obsolete the Appalachian subsistence and general farm, and a few years later the Greek mountainous subsistence farm.

BREAKING UP OF THE RURAL MOUNTAINOUS COMMUNITY

One of the most important consequences of the technological changes mentioned earlier was the rural community's increased socio-psychological identification with the city. Villagers in Appalachia and mountainous Greece, who because of this new linkage felt more a part of the larger society, started using it more than before as their major reference group. The new reference group emphasized more material comfort and less the rural way of life. In turn, older ways of securing satisfaction, including the entire family's involvement on the subsistence farm, became less desirable. These patterns of rural change are considerably different in Appalachia than on the plains and more so in regions of high agricultural potential.[5]

The few Appalachians who had already out-migrated during and immediately after the war years contributed to extra-community interaction and communication through their visitations and other contacts. From the theoretical point of view, interaction and communication are the two most crucial processes facilitating the incorporation of one social system into another and the weakening of an older system. In other words, a crucial indirect function of the availability of jobs in cities neighboring Appalachia, and later in the cities of Greece and Germany, was the weakening of the boundary maintenance mechanism of the rural social system and, furthermore, the increased use of the city as reference group. Starting first with the younger, more educated, rural Appalachians increasingly began comparing their incomes and levels of living with outsiders, the urban lower middle class in particular. From this point on, both out-migration and socio-psychological linkage steadily increased, together with the incorporation of the rural into the larger social system, the local use of the latter as a reference group, and in turn, the community dwellers' strong feelings of *relative deprivation*.[6] In addition, because such feelings had been internalized by large numbers of individuals, social pressures rapidly increased for performance in line with expectations of the larger society. This led to more out-migration and, in turn, closer dependence upon the larger society, which in turn further increased out-migration. In other words, job opportunities in the city made this mutual dependence between migration and incorporation into the larger society possible. Regardless of physical, cultural or mental suitability or preparation for city employment, within less than two decades almost all young adult men and women left rural Appalachia and a few years later, mountainous rural Greece.

Together with the rest of the rural social system, boundary maintenance mechanisms (for instance, norms suggesting that you cannot find a true friend in the city, and that the good life is found in the hollows) began quickly losing their effectiveness. On the other hand, internal and external pressures for economic achievement, and in turn out-migration, rapidly increased to the extent that for many, the rural community became a negative reference group. Community norms became ineffective, morale declined, and in a number of cases the rural social organization almost collapsed. This stage of transition, which is initiated and usually sustained by the availability of city jobs, often leads to a mass exodus of rural populations. From the point of view of action programs, understanding these processes is important because:

First—At a certain point in the transition, out-migration occurs much faster than city employment can absorb.

Second—Migration pressures draw people out of their communities regardless of their preparation or fitness for city life, thus creating a number of subsequent socioeconomic problems.

Third—Already-fragmented land is hastily deserted and no plans for proper utilization are made for many years. If there were an awareness of the

[5]See John Photiadis and Richard Ball, "Patterns of Change in Rural Normative Structure," *Journal of Rural Sociology*, Volume 41, No. 1, pp. 60-75, 1976; John Photiadis, "Changes in the Social Organization of a Village," *Sociologic Rurals* (the *European Journal of Rural Sociology*), Volume 16, No. 1-2, 1976. Also, see John Photiadis, Leonard Sizer and Jim Way, "Migration and Occupational Adjustment in the City," Office of Research and Development, Center for Extension and Continuing Education, West Virginia University, 1974.

[6]Deprivation at this point refers to both income and city life, and as we have indicated is the direct consequence of the use of a new reference group (the group one compares himself with) which in this case is the city.

processes we describe here, administrative plans could be made so that, through suitable farm loans and other means, a number of farmers could be encouraged to remain in the village, and under some encouragement gradually utilize deserted and public land in a more profitable kind of agricultural enterprise. A typical example would be the gradual increase of herds of beef cattle coordinated with the pace of out-migration. This effort would be particularly useful for some farmers, for instance those who are expected especially to have problems adjusting in the city.

Fourth—This type of exodus is taking place today in a number of developing societies. Typical of this problem is the large number of unemployed young men wandering around big cities in Asia, Africa, and South America, and families living in squalor on the periphery of such cities. When these people are asked whether they like this style of life better than that in their villages, they tend to respond negatively; and when asked why they left, for at least the first few years after out-migration they usually don't have a specific explanation.

It is obvious, and in particular after the breaking up of the rural community, that these processes are influenced by the factor "income differential" between rural peripheries and industrial centers; the greater the difference, the faster the out-migration.

Due to less extensive isolation and more agricultural potential, the incorporation of the rural into the urban social system was much more gradual in the plains of the United States and Greece. This is particularly true in areas where agriculture is a more viable option and land can be consolidated into economic units. In most cases this was not feasible in the hollows of Appalachia and the mountains of Greece. The same is true in other countries when one compares fertile plains with isolated, low-income mountainous areas.

ORGANIZATION OF THE MOUNTAINOUS RURAL COMMUNITY

Societies adjust to important environmental changes primarily by reorganizing their internal dynamics and relationships. Considering that the current emphasis is on material comfort, more than any other aspect the occupational adjustment of young and old both in Appalachia and mountainous Greece becomes the focus of change. Thus the father leaves his subsistence farm and often moves to the city or into semiretirement or part-time farming, while children move to the city or go to school to eventually secure better means for the possession of material goods. In other words, changes in other major social institutions or their parts have to a large extent played a supportive role, sometimes secondary and tertiary, in implementing changes in occupational expectations.

For instance, changes in government and education often had as a purpose the development of means for securing a more rewarding job; but others, for instance the family, have changed in such a way that they can both facilitate occupational development and also act more or less as a buffer absorbing social, economic, or psychological dislocations produced by changes in occupational expectation and in hill farming itself. Finally, other institutions, the church for instance, increasingly perform these two functions originally performed by the family. Rural sectarian fundamentalist religion reversed its earlier decline in the years after World War II. As we have indicated, this was the period when rural Appalachians were most pressured for achievement in the larger society. As our empirical data indicate, there was at that time more alienation in the small as compared to the medium and large community in West Virginia, and more need to alleviate anxiety through religion and in particular that of the more emotional type.[7] But rural Appalachian religion is pluralistic, flexible, and therefore adapted to the new needs of rural people. This was not the case in Greece, where the rural church is an inflexible and monolithic institution[8] and therefore unable to satisfy new needs sufficiently. In rural Appalachia these churches offer both intimacy for the farmer who was forced to retire, lose his status and even his children, and also the comfort of a doctrine which helps the adherent forget his difficulties.

Besides reorientation of major institutional subsystems during the 20-year period for Greece and 35-year period for Appalachia, the rural community has been undergoing changes in all parts of its basic social structure, so that closer integration into the larger society might become easier. Thus we see general trends toward the differentiation and specialization of occupation, norms, statuses and goals. These constitute important processes leading to the new type of integration within the rural social system. Thus new internal integration is expected to facilitate the more functional integration of the rural into the larger society.

Occupational specialization among farmers is more visible in the plains of Greece and in the productive agricultural regions of America, where it is characterized by increased professionalization and other positive attributes. But this has not been the case in mountainous Appalachia where, as we have mentioned, part-time farming has now become predominant. Obviously, little interest in part-time

[7] John Photiadis and Beryl B. Maurer, *Community Size and Social Attributes in West Virginia*, Appalachian Center, West Virginia University, Research Report #5, 1972.

[8] John Photiadis and Joe Simoni, "The Changing Rural Religious Institution," paper presented at the Fourth World Congress for Rural Sociology, Torun, Poland, August 9-13, 1976.

farming existed two decades earlier when the majority of farms were simply abandoned. According to the latest information obtained from the mountainous regions of Greece restudied twenty years later,[9] abandonment has also become a common occurrence there. As a matter of fact, in the two most isolated of the nine villages studied, only one villager was left in one and probably two in the other, who had accumulated a relatively large herd of improved beef cattle. The herd used the 50 or 60 village homes as barns. In the less isolated villages the more professionally developed herds fed on public pastures and the abandoned land fragments of peasants who had out-migrated.

In rural Appalachia and West Virginia in particular, part-time farming is now pervasive and is in the process of becoming institutionalized, thus creating a completely different kind of steady clientele for the extension services. Many of these people consider their non-farming jobs as their main occupation and therefore enjoy comparatively limited contacts with government agriculture services. Among these part-time farmers are a number who are partly retired, some on welfare, and others supported by other sources including relatives. Several farmers have come to semi-retirement much sooner than the normal retirement age for the region. Some have in some ways retreated from society and often exhibit lifestyles which are not considered conventional. For some this retreat entails closer attachment to the sectarian fundamentalist churches, while for others it involves partial attachment to traditionalism (often including hunting and fishing) and association with families with similar strained relationships with the larger society. As mentioned, this strain is often caused by unfulfilled expectations of economic rewards. Through the years a few of these families developed attributes of what we may call a "culture of poverty." This is often a transition of certain respectable poor families of the twenties and thirties into a new cultural configuration. In some cases this configuration has become almost institutionalized, in large part because of the birth and socialization of young children within it. Thus, in spite of the now rapid socio-economic improvements in Appalachia these families remain static, and will probably remain so for some time in the future. It is therefore important that change agents working with these families are aware of the reasons for their retreat. Otherwise, at least for some, programs involving raised expectations which for one reason or another are difficult to attain, might have the opposite results.

[9]John Photiadis, "The Study of the Social Organization of a Mountainous Village." Ibid.

In general, cooperation of extension agents with semi-retired farmers of this type is even more difficult than work with the part-time farmer who usually avoids involvement because he sees non-farm employment as his major pursuit.[10] As we have pointed out in the first part of this paper, the behavior of this group often coexisted initially with a tendency for retreat from society because of what we call "feelings of relative deprivation"; in other words, in comparison with others one does not receive the anticipated reward for the physical efforts required by one's employment. Such feelings did not exist before the breaking up of the rural community in Appalachia and Greece. As a consequence, policy planners should be aware that if hill farming is to succeed, such feelings should not develop. On the other hand, it may be that in the future, changes in overall attitudes emphasizing material comfort less than before and the rural way of life and farming more, might reduce the amount of income required to avoid such "feelings of relative deprivation." Attitudes of this kind are increasing even among city people in the 1970's, and as explained below are already influencing rural settlement patterns and hill farming in Appalachia.

Semi-retired part-time farmers are often more responsive to extension agencies than part-time farmers who were not previously farmers. As a consequence, a new professional orientation is necessary before these people utilize the extension service and other government agencies. Considering that these part-time farmers are often well-adjusted socially, proper efforts to approach them might be fruitful. A study conducted in North Carolina has shown that a sizeable number of part-time farmers profited from a five-year demonstration project in cooperation with extension agents.[11] In large part, changes among these farmers involved their increased participation in voluntary associations. For Appalachia, where farmers in general participate less frequently in formal organizations than elsewhere, these changes should be considered quite useful. Finally, the switch from full-time to part-time farming while securing another job, versus part-time farming combined with some form of retreat from society, is associated with proximity to a job market, the individual's value and religious orientations and the way he relates to his social environment.

In mountainous Greece, where the impact of the larger society on the smaller community occurred

[10]For relevant information see Glenn V. Fuguitt, "Career Patterns of Part-time Farmers and Their Contact with the Agricultural Extension Service," *Rural Sociology*, Vol. 30, No. 1, 1965. Also see "Mobility from Full-time to Part-time Farming," *Rural Sociology*, Vol. 32, No. 2, 1967.

[11]T. Gilbert Hardee, "Planned Change and Systemic Linkage in a Five-year Extension Program with Part-time Farm Families," *Journal of Rural Sociology*, Volume 30, No. 1, 1965.

later, some of the discords mentioned previously are not yet as extensive; but early retirement and semi-retirement of farmers together with feelings of relative deprivation when engaged in farming, are quite extensive. Most often the income of these people is supplemented by support from relatives in the city and the Greek Government's new social security programs. These programs benefit farmers of retirement age, including those with very little previous contribution to the security system. Thus in spite of the presence of feelings of relative deprivation and the consequential lack of interest to remain in farming, social discords and tendencies for retreat within the community are, at least for the present, less frequent. Two additional reasons for this trend are, first, that the breaking up of the rural social system occurred later than in Appalachia and therefore, there has not been sufficient time for some discords to develop; and second, in contrast to the large majority of Appalachian farmers, Greek mountain peasants do not possess automobiles, and thus usually depend exclusively on the village community for association. In addition, the Greek village system is centralized, interaction within local coffeehouses is extensive, and therefore social control is more effective. Furthermore, and at least among older men, associating within the coffeehouse often serves as a substitute for the loss of the extended family, the loss of status within the family,[12] and the lack of religious forms suitable to the alleviation of anxieties.

REFLECTIONS AND TRENDS

The Appalachian region is about 400 km wide and several hundred km long, consisting of low-altitude, highly forested mountains, difficult to penetrate under normal conditions. As a consequence, community and kinship systems became highly cohesive. Both systems were based on integration patterns initiated in large part within the daily life of the subsistence farmstead. Thus, until a few decades ago, the interplay of social and economic forces within the local system allowed subsistence farming to function largely independently of the larger economic system. This was the case until the 1940's, when technological changes triggered unique social pressures that in turn led to the disintegration of the rural social system and the subsistence mountain farm. The size and nature of the Appalachian mountain region, the recency of settlement, the lack of rural transportation routes, and the region's very existence within the highly complex American culture, all comprised the initial ingredients that allowed technological changes to bring about the rapid breakup of the rural social system. Understanding the uniqueness of this breakup is important for everyone dealing with Appalachia in transition, for the following reasons: first, it brought about both drastic and rapid changes in most rural social institutions, including farming; second, it offers clues to the nature of changes that might follow the present discords which exist in most mountainous and especially herding communities throughout the World;[13] third, action programs can be planned on a more realistic basis; and fourth, certain future rural trends can be predicted more easily.

In this light we present below some of the future trends in rural Appalachia hoping that, at least in some respects, they will serve as guidelines for pinpointing similar trends in rural mountainous societies elsewhere.

Trends which have already developed indicate a more conventional type of integration of rural Appalachia into the larger society. Economic and specifically agricultural integration will probably be based, at least for the large majority of people who are not in retreat from society, on economic rationality, to a lesser extent on the individual's belief and value orientations toward the rural way of life. The integration of those working in the rural coal mining industry will probably be based even more on economic rationality than the integration of those employed in agriculture. Furthermore, integration of both groups will be based on new and old values, but the retention of many of the old values will not be caused by tendencies for retreat due to inability to cope with expectations of the larger society, but simply because a number of the old Appalachian values, at least today, appear to be more functional than those of the larger society. This broader and more functional value orientation will probably contribute to the building of a more flexible rural social organization capable of absorbing the consequences which the new economic potential through proper utilization of the vast coal reserves parts of Appalachia might bring.[14] This will probably include reduced social conflict when outsiders move into the region and introduce still other technological changes. But integration of groups which are characterized as "systems in retreat" will probably be much slower, and this will include groups which are targets of action programs.

Finally, in the relatively distant future, trends in social forms of rural Appalachia will be determined, in large part, by the way the region fits into the

[12]His wife tends to treat him as before, but not his children.

[13]Because of their constant movement and in turn more limited interaction and communication with the larger society, the integration of this latter group into the larger society usually occurs later.

[14]From the coal production point of view this potential has become more important since the energy crisis.

emerging new ecological system. As it appears now, the new social forms will probably be determined by such basic factors as coal reserves, proximity to the megalopolis, physical attraction of the region, and potential for the preservation of social systems able physically and culturally to remain relatively autonomous from the larger society.

DISCUSSION

Stephen Brush (Virginia, USA). In the Andes where I worked, some of the rural social systems are described as being a function of internal colonialism in the country; others are independent of this. That is, depressed backward areas in the highlands are seen as reserve pools of labor willing to work at low wages. People no longer control commodity or resource prices and changes in these systems are seen to be a function of radical or even revolutionary change. Could you comment on this with respect to Appalachia? Do you see any similarity?

Photiadis. Colonialism then did what isolation or the mountains did in Appalachia. But concerning Appalachia there were opportunities in U.S.A. cities to fulfill raised expectations. Otherwise the greater the discrepancy between expectations and achievement the greater the possibility for radical reaction including revolt.

G. C. Anderson (West Virginia, USA). Most of what we have heard this morning has been descriptive. I can appreciate the necessity of this, and yet I have not found very many positive suggestions as to how change can be accomplished, for the well-being of the people who live in marginal areas who are subsisting satisfactorily now but are increasingly pressured from the industrialized world and from population, how adjustments can be obtained with a minimum of dislocation and discomfort. What suggestions can a social scientist make to the agricultural technologist as to how technology can be most effectively incorporated in a pattern of life to improve human well-being? I find little encouragement. Yet, on the other hand, I am increasingly concerned that the human factor still is a major item and we have no suggestions, really, of how we can go about taking care of it.

Photiadis. If you try to block those people, you'll fail because the pressures are coming in, the reference groups will be shifting. What you should do, and this requires very skilled professionals, is to shift the reference groups from the larger society to some local groups which are a little higher but not much, or selected groups elsewhere, e.g., a place where cooperative farming has been successful. In other words, the reference group should have attributes in line with the objectives of the government and attainable; mass media can do a lot when used by experts, including shifting of reference groups. Information about the "back to nature movement" in U.S.A. is one of the many arguments planners could use. This kind of planning is more important for countries without opportunities in cities and for people, who, according to research reports, tend to have adjustment problems.

Anderson. All right, but this is only an exhortation; you've got to have something better than that. I'll believe you for a while but eventually I'll see that there's something else better than this rural isolation. There must be some better way to live.

Photiadis. Agricultural development is not my business. If you can do it, that's the best. But how can you do it?

S. A. Almy (New York, USA). There's not very much that the agricultural technologist can do. I think the agricultural technologists should be the clients of the planners. Then we work together rather than each saying that we alone can provide a solution. When you come in and say that we're going to solve your problems by providing better technology to the peasant and I come in and say change your land structure, neither of us is going to help. People probably won't listen. I think there's a chance that people do listen a lot better if the technologist is also saying some of these things—if the social scientist and the technologist are coming into an area together and trying to show what should be done as part of a unified strategy. We can say a little bit about what you should do about gene pools and what you should do about the fact that the farmer over there is not accepting hybrid maize this year, but we can't tell you a great deal about what you should be doing about it because a lot of these problems are basic to the societal structure, and they are problems of the government, and of the international community rather than of the technology.

Anderson. You suggest that government is a tool, a very necessary tool, to implement these changes, yet governments seem to be slow in response. One of the items that came out, I agree with you, is inferred by what you said: the detailed knowledge that the subsistence farmer has of the system that is supporting him should be appreciated by outsiders. Do we know enough about the human systems that function there as well as the food production systems that function so that we can have respect for him and he in return can rely on what both the social scientist and the biological scientist would have to say about changing and improving things?

Almy. Maybe this is part of my general optimistic picture of life, but I figure if you've got respect for the farmer, enough to listen to him in the first place, the social scientist can help you out but you're going to have won just half the battle.

Harry Schwarzweller (Michigan, USA). I think what we're getting into is this huge question of facts, which we sometimes call descriptive information about societies and concepts. The definition of problems has value content, and what may be a problem to a peasant farmer may not be a problem to a social scientist, and vice versa. Howard Beard many years ago said that social change solutions might result if we honestly blunder into the areas of trying, somehow, to bring about an effective social change that is for the well-being of people in general. But when we start talking about the well-being of people we sometimes run into the problem of what boundaries we put around people. In many of the papers that we've heard here, yesterday and today, boundaries are put around small groups, or sometimes nation states. The world is no longer that way. There is an old problem in anthropology, called Galton's Problem, in which diffusion of knowledge creates an interactional effect among many societies around the world and it becomes very difficult to separate what is peculiar or cultural here and what is unique and different over there.

W. Berry (Pennsylvania, USA). I feel that as long as expert advice remains expert advice it can never become a solution. What this conference exemplifies to me is the difficulty of keeping expert advice from being bottled up in the universities and the government. There are no farmers at this meeting and very few young people. What we need are not demonstration farms and experimental farms, we need prototype farms and they're going to have to be established if we're going to have solutions by people who go out and work on the farms and make money from them. As long as a new plant or a new method is on an experimental farm the main question about it, whether it can provide a livelihood, is never answered. As long as that sort of question isn't addressed, expert advice is going to attempt to provide a solution by imposing itself, by condescension, arrogance, and ignorance on what already exists.

Schwarzweller. Yes, but you must also recognize that sometimes the persons who have great ability to conceptualize may not be the kinds of people who are able to talk with farmers. You have to think of it in terms of levels of expertise and work. Some social scientists are able to relate to other social scientists, who are in turn able to relate to persons at the farm level. I for one would advocate that every one of my students get out on the farms. There are very few rural sociologists around this country who ever see a farm or know one end of a cow from the other. Anyone like to comment on that?

Unidentified. I'm not a professional in any of the fields discussed here, but it did seem to me that the point that our speaker was making and the point that this gentleman has just made come together. I'm on a planning board and have lots of ideas and a little bit of background about how things ought to go. But I also have to deal with how the people in my town feel. I'm a relative outsider unless I can find the kind of people who you were talking about, who have been there for a long time, and who understand and espouse the kinds of things that I think are going to be better and help us to solve our problems.

You have to be able to communicate with the people to whom you are speaking. People who are experts but who are right there, resource people from the community, can help in a very exciting and probably the most effective manner. Efforts are made in this direction up in New Hampshire, using local experts to teach other people how to do things. I think we need to utilize these skills in a better way.

Photiadis. I meant package information, for a county extension agent, home economics or 4-H agent; subject matter which is not agricultural per se but containing objectives which give it special dimension.

Unidentified. These objectives today are as real as farm practices but we have not made them salable.

Schwarzweller. Anyone else like to make a comment?

Berry. Well, let's consider the county agent. Say you came to a relatively poor rural section, and the county agent is there as an expert, going around and showing the people how to do things, by advice. If that county agent would live there and exemplify how one might live well locally, as the local people with their resources might live, then you've got something else. He represents a possibility. Otherwise he just represents outside information and he isn't paid a great deal of attention.

Schwarzweller. You're making a point, I think, using the county agent as one to demonstrate what he believes in. That's well and good, but I also have a firm faith in the rationality of the people and the ability of people to see what is good for themselves and what isn't, and to use their own minds in their own situations as devices for screening out the kinds of things that other people might be telling them. Not simply because other people are demonstrating how well they can do living that way, but also because the people themselves are able to think through, to conceptualize, how some innovation may affect their own life-styles regardless of whether the demonstrator has on a tie and a suit and comes

from the middle of New York. I have worked with Appalachian people in the mountains quite well, and I know they sort things out. They reject some and some they accept. No one will ever be a good change agent unless he has a deep respect for the ability of peasants and "hillbillies," or whatever, to think rationally about their own situations. I think that part of the problem sometimes is that experts seem to lose sight of that ability of the average person to see.

Berry. But you mustn't also lose sight of the ability of the average person to be influenced by social class and the fact is that these communities and small farms are breaking up in large part because people think it's better to buy milk at the grocery stores than it is to get it from the cows. The subsistence basis of their lives has been destroyed, not by anyone's rationality but simply by social classes. I know of farms where the milk goes to the stock. The people get milk, but delivered in bottles at a $1.75 a gallon.

Photiadis. How else do you reach rural people? What do you suggest if you do not give this information package to the county agents? What should we do, bring every farmer from Appalachia into international conferences? What can you do? That's the only way teaching goes. If you have a better method, tell us what it is.

Berry. Let the county agent milk a cow.

Anderson. Some of you might know a project undertaken here which dwells right on your subject. It's called the Allegheny Highlands Project. I would like to call on Dr. Baker, who is the Agronomist involved in this project, and have him make a few brief comments about it because it's so relevant to what we've been speaking about.

Barton Baker (West Virginia, USA). I listened with great interest to the comments that were made and, I'll say that there have been many days when I wished that I had some background in sociology as well as agronomy. When our project started we were working with small Appalachian farmers, or at least what we thought were farmers. At the present time, we are working with 72 such farmers on what should be thought of, perhaps, as a contract basis. We have a veterinarian, animal scientist, farm economist, and an agronomist who work with these people and try to provide a package approach for them. Now, I noticed as I listed the staff, that they are all technical people, and I feel that after six years we have been pretty successful in terms of answering technical questions. The thing that I would present to you is that many times we have tried to solve what we think is the farmers' problem, but they don't consider it to be their problem. They have a different set of priorities than ours, and I'm not sure that sometimes they can put into words what their priorities are. Certainly they function differently depending upon the particular family and individuals' motives. Maybe they don't milk the cow, not for financial reasons, but maybe they don't want to be tied down morning and night 365 days a year and they're willing to pay $1.75 for a gallon of milk every day so that when they do want to take off for a weekend they don't have to worry about getting back at 5:30 in the afternoon. And repeatedly you see things where they have put certain things in higher priority than what we as technical people might put in higher priority, usually dollars or standard of living. I now realize that many things go into "quality of life."

Unidentified. Just one brief comment. I am a product of Appalachia. I've gone through this turmoil of having economic and social roots disrupted, and I also have gone through the putting back of the pieces. I would thank Dr. Anderson because he helped me do this; I was his student in the past. I don't look at myself as a government employee out on the grass roots level. We have to deliver, thus I'm a public servant. I work with people. I wouldn't go to a man's country and try to immediately impose a capitalistic viewpoint or something else in a way of economic values. I would put myself on his level and then work from there within his structure, within his social structure. It's not difficult to get the Appalachian farmer to turn out to meetings if you work with him, if you talk with him. I applaud the Extension Service greatly but I also find faults: that of a typical county agent realizing the farmer's priorities and presenting information in a fashion that he'll be able to accept, in the amount that he can handle at the time within the capacity that he has to deal with it. Thus, I do think that one does have to be somewhat of a sociologist as well as a technician. We have to temper our advanced knowledge, technical knowledge, with their social values. I don't know how else to talk to a man, woman, or child, whether it be in Appalachia or in an urban area, unless I get myself on the level, in some respect, of where they stand.

Alex Tainis (Haiti). Dr. Photiadis, you have described the phenomenon in both developed and developing countries, but in my opinion you have stopped half way, as far as the developing countries are concerned. All of these comments are made mostly for the United States and other developed countries but, you see, the picture is entirely different in the developing countries. In the developing countries we can't speak about farmers but only about illiterate peasants. When this outflow of peasants leaves the agricultural sector to go, for example, into town they can't be hired by any organization because they are not skilled people. So they are going to live in the suburban slum and increase

delinquency. On the other hand, we can't encourage them to live and stay in the country as farmers or peasants, taking into consideration the pressures on the land. If they continue to live on the land and if they can't make a living, what they are going to do is to split the land again and again and reduce the productivity. I would like to have your comments.

Photiadis. What I suggested is to control the outflow—first do things within the community like, for instance, helping people determine their reference groups. I know that in Kenya, for instance, the villages have been deserted as in Greece. Here in Appalachia they just left everything. In the plains, this phenomenon does not take place. When he needs room for expansion, one farmer leaves and the rest rent his land and the transition is much more gradual. The breaking up of the system refers to mountainous communities and this is the main difference, in terms of change, between mountainous and non-mountainous communities. So what we can do is to control this outflow and then have more time to inform people about migration, teach them about adjustment in the cities, teach them skills and at the same time take some individuals and say: "Now I'm going to give you extra loans to consolidate your land." In other words, change your objective completely, not in relation to what it is today but in relation to what it will be in 10, 15, or 20 years.

21.
Pasture Establishment on Unplowed Hill Land in New South Wales, Australia

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New South Wales (N.S.W.) has more than four million hectares of steep hill land which could be improved by using aerial techniques to establish pastures. Much of this land is dominated by low-producing native grasses, nitrophilous weeds, and the perennial weeds *Nassella trichotoma* and *Hypericum perforatum*.

The native grasses which occupy most of this hill land are damaged by frost and thus produce little in winter, the season of pasture shortage. Nitrophilous weeds (Table 1) have invaded large areas of hill land partly improved by aerial application of *Trifolium subterraneum* and superphosphate, resulting in inferior, unstable, drought susceptible pastures. *N. trichotoma*, a perennial grass which infests 0.72 million ha of N.S.W. is unpalatable, spreads rapidly and is difficult and costly to control on non-arable land (Campbell, 1974a; Campbell and Barkus, 1965; Campbell and Irvine, 1966; Vere and Campbell, 1974). *H. perforatum*, a perennial herb which occupies another 0.18 million ha of N.S.W., causes dermatitis, digestive upsets and even death in cattle, sheep and horses (Hurst, 1942).

The hill land in N.S.W. has a temperate climate with relatively high rainfall (400 to 800 mm/year) and high productive potential. To increase its production the existing weedy pastures must be replaced with persistent perennial species which give long-term botanical stability (Campbell, 1974b). Thus research in N.S.W. over the past 20 years has investigated the use of aerial techniques for the improvement of hill land dominated by inferior native grasses, nitrophilous weeds, *N. trichotoma* and *H. perforatum*.

METHODS

The experiments were carried out on four hill land sites varying in altitude from 600 to 1000 m on the central tablelands of N.S.W. Climatic data for a representative site is given in Table 2. The main resident species on the four sites and their percentage ground cover before treatment are shown in Tables 1 and 6. Experiments were conducted on small plots using randomised block designs with three to six replications. Herbicide, seeds and fertilizers were applied to the unplowed land by hand.

TABLE 1. Main resident species in the four situations investigated, before treatments were imposed

Native grass pasture	
Perennial grasses:	*Bothriochloa ambigua, Themeda australis, Danthonia pilosa, Poa labillardieri, Stipa scabra.*
Annual legumes:	*Trifolium glomeratum, T. campestre, T. subterraneum.*
Annual grasses:	*Vulpia* spp. *Briza minor, B. maxima.*
Broadleafed plants:	*Hypochoeris radicata, Cymbonotus lawsonianus, Hydrocotyl laxiflora, Plantago debilis.*
Nitrophilous weed association	
Perennial grasses:	*D. pilosa, B. ambigua.*
Annual legumes:	*T. subterraneum, Medicago arabica, M. scutellata.*
Annual grasses:	*Hordeum leporinum, Bromus sterilis, B. mollis.*
Broadleafed plants:	*Silybum marianum, Carthamus lanatus, Cirsium vulgare.*
***Nassella trichotoma* pasture**	
Perennial grasses:	*Nassella trichotoma.*
Annual legumes:	*T. dubium.*
Annual grasses:	*Vulpia* spp.
Broadleafed plants:	*H. radicata, Acetosella vulgaris.*
***Hypericum perforatum* pasture**	
Perennial grasses:	*Microlaena stipoides.*
Annual grasses:	*Vulpia* spp.
Broadleafed plants:	*Hypericum perforatum.*

TABLE 2. Monthly rainfall, evaporation, and temperatures at Bathurst (33°25′S; 149°34′E; 704 m) on the central tablelands of N.S.W.

Month	Rainfall (104 yrs)	Probability of Obtaining Effective Rainfall*	Evaporation (28 yrs)	Screen Temperature (76 yrs) Max.	Min.
	mm	%	mm	C°	
January	63	56	188	29.9	13.0
February	56	47	152	29.1	12.8
March	51	54	133	26.2	10.5
April	43	66	82	21.7	6.1
May	43	73	50	17.0	2.5
June	49	94	31	12.8	1.1
July	45	90	32	12.2	0.2
August	45	89	47	14.3	0.7
September	45	81	74	17.8	3.0
October	57	70	107	22.0	6.0
November	57	58	140	25.6	8.8
December	60	48	173	28.5	11.5
Total	614		1 209		

*Effective rainfall (P) is defined as $P = 0.8E^{0.75}$; that is, the amount of moisture required for a newly germinated plant to establish in a dormant pasture (Prescott, 1956). E = Evaporation.

RESULTS AND DISCUSSION

Competition

In each situation it was essential to reduce competition from resident species by herbicide application to allow the establishment of the perennial species (Table 3). The annual *T. subterraneum*, however, established without the aid of herbicides, probably because of its greater seedling vigour.

Table 3 shows that some plants of perennial species were present on the minus herbicide treatments three months after sowing. Almost all of these were killed by competition during their first summer, whereas plants on the plus herbicide treatments survived in sufficient numbers to form a good pasture (Campbell, 1968; 1974c). Thus it proved necessary in each situation to kill or retard the resident species from the time of spraying (late summer or autumn) until the following autumn.

Different herbicides were necessary in each situation. The native grasses were retarded by 2,2-DPA (sodium 2, 2-dichloropropionate) or glyphosate (N-phosphonomethyl glycine) (Campbell, 1976). Where superphosphate had promoted annuals amongst the native grasses, simazine, 2, 4-D or amitrole had to be added to the 2, 2-DPA (Campbell, 1974c; 1976). The nitrophilous weeds were controlled by 2, 2-DPA + 2, 4-D, 2, 2-DPA + amitrole, paraquat + diquat or glyphosate. Where perennial grasses were prevalent, high rates of 2, 2-DPA or glyphosate were necessary.

It was necessary to kill *N. trichotoma* with 2, 2-DPA or tetrapion (sodium 2, 2, 3, 3, tetrafluoropropionate) so that surface-sown species could replace it entirely (Campbell, 1974a).

A mixture of 2, 4-D ester + 2, 2-DPA or glyphosate alone controlled *H. perforatum* and the associated *Vulpia* spp (Campbell, *et al.*, 1975).

Campbell (1963) and Campbell and Swain (1973) showed that the optimum time for surface-sowing in N.S.W. was late autumn, because effective rainfall was most reliably received during the following winter (Table 2). To coordinate the timing of herbicide application with this optimum time of sowing, it proved necessary to apply herbicides in autumn, after rain had germinated resident weed seeds, and to allow a period between spraying and sowing for the residual herbicide to dissipate. For example, where native grasses and winter annuals were associated, establishment was achieved by applying glyphosate or 2, 2-DPA 10 to 30 days after autumn rain and then sowing 10 to 20 days later (Campbell, 1976). This technique was also suitable for the nitrophilous weed association and the *H. perforatum—Vulpia* spp. pasture.

In some areas of N.S.W. nitrophilous weeds are sprayed in early winter and the pasture seeds sown

TABLE 3. Effect of herbicide in reducing competition from resident species on the establishment of surface-sown species, three months after sowing

	Medicago sativa	*Trifolium subterraneum*	*Dactylis glomerata*	*Phalaris tuberosa*
		Plants/sq m		
Native grass pasture[b]				
+ herbicide	6.1 a[a]	2.1 a[a]	9.9 a[a]	4.9 a[a]
- herbicide	0.6b	2.3 a	0.8 b	0.2 b
Nitrophilous weed assoc.[c]				
+ herbicide	7.6 a	—	—	42 a
- herbicide	0.1 b	—	—	4 b
***N. trichotoma* pasture**[d]				
+ herbicide	—	20 a	44 a	11 a
herbicide	—	17 a	26 b	4 b
***H. perforatum* pasture**[e]				
+ herbicide	—	10.5 a	6.0 a	18.0 a
herbicide	—	8.7 a	0 b	0 b

[a]Means followed by the same letter were not significantly different at the 5% level of probablility; comparison between pairs.
[b]Campbell (1974c).
[c]Campbell, unpublished data.
[d]Campbell (1968).
[e]Campbell, Flemons and Dellow (1975).

between late winter and early spring (Wheatley and Phelps, 1973).

To control *N. trichotoma*, 2, 2-DPA must be applied in late summer and the pasture seed sown in late autumn. The disadvantage of this treatment is that annual weeds may establish in the three months between spraying and sowing. As tetrapion is efficient in killing *N. trichotoma* in autumn, it can be applied one month before the optimum sowing time of late autumn thus reducing the time available for the establishment of competing annual weeds.

Seedbed

A seedbed is prepared on unplowed hill land by avoiding grazing before application of herbicide. The seedbed reduces moisture loss from the establishing seedling and can improve establishment by 400% (Dowling, *et al.*, 1971). However, under wet conditions, it can harbor insects and slugs which reduce establishment. For the four situations referred to in this article a mixture of bare ground and dead plant seedbed is preferred.

Treatments Before Sowing

Seed-harvesting ants (*Pheidole* spp.) which are widespread in N.S.W. take aerially sown seed (Campbell, 1966). By treating the seed with dieldrin before sowing to control ant theft, establishment was markedly increased (Table 4). Relatively large seeds were least preferred by the small ants. Loss of seeds was greatest when dry conditions followed sowing.

TABLE 4. Effect of treating surface-sown seed with dieldrin to reduce losses due to seed-harvesting ants

Species	Number of Plants to Establish[a] Plus Dieldrin	Minus Dieldrin
	Plants/sq m	
Trifolium pratense	22	10
T. repens	25	11
T. subterraneum	13	8
Lolium perenne	16	3
Dactylis glomerata	42	7
Phalaris tuberosa	4	1

[a]Mean of ten sowings over two years (Campbell, 1966).

It proved essential to inoculate and coat legume seed with lime when aerially sowing on acid soil (Hely, 1965; Campbell, 1968). The inoculation and pelleting was done after dieldrin was applied.

Species

Most pasture species used in N.S.W. (Tables 3 and 4) establish from aerial sowing if competition from resident species is reduced. Percentage establishment of viable seed varied from 1.1 to 39.8% (Campbell, 1974c; 1976). A level of 8% establishment of viable seed is regarded as suitable as it would provide, respectively, 5.8, 9.0, 12.6 and 14.9 plants/m^2 of *T. subterraneum*, *Dactylis glomerata*,

Medicago sativa and *Phalaris tuberosa* for sowing rates of 4.7, 0.9, 3.3 and 2.1 kg viable seed/ha (Campbell, 1974c).

Fertilizers

As most hill land in N.S.W. is deficient in phosphorus, superphosphate must be applied to virgin land to allow legumes to establish from aerial sowing (Table 5). Usually pastures dominated by native grasses, *N. trichotoma* or *H. perforatum*, have had little superphosphate before improvement; thus application is essential. Nitrophilous weeds occur where superphosphate has been applied over a number of years, thus further application after treatment depends on the level of phosphorus built up in the soil.

TABLE 5. Effect of superphosphate on the number of *Trifolium subterraneum* plants present in the second spring after surface-sowing and fertilizer application

Rate of Superphosphate Year 1	Year 2	*T. subterraneum* Plants
kg/ha		Plants/sq m
0	250	14
125	250	79
375	250	173
625	250	104

Management

In most situations the treated area was not grazed from before herbicide application until the following autumn to allow the plants which established to seed. In some seasons it was necessary to graze the nitrophilous association in the first spring to reduce competition from annual grasses. Spelling treated sites in the second and third spring and summer periods assisted the improved species to become dominant (Table 6). On the native grass site, plant density of *M. sativa* and *D. glomerata* was increased by 800% and 500%, respectively, due to strategic grazing after the improved species had completed their third seeding (Campbell, 1974c).

Production

On the native grass site, *M. sativa*, *T. subterraneum*, *D. glomerata* and *P. tuberosa* were surface-sown on unplowed hill land after herbicide application in each of the last nine years. These species established well and persisted under rotational grazing (Campbell, 1974c). Their dry matter production (Campbell, 1974c; 1976) was compared with that of the adjoining pastures; one where *T. subterraneum* and superphosphate were aerially applied and one where no treatment was imposed. Production and quality was higher where perennial species were established (Table 7).

TABLE 6. Botanical composition of resident species on the four experiment sites before and after application of herbicide, seed, and fertilizer

Site	Native Grass	Annual Legume	Annual Grass	Broad-leafed Plants	Improved Species
			% Ground Cover		
Native grass pasture[a]					
before treatment, autumn, 1973	62	15	6	10	0
after treatment, autumn, 1975	12	14	7	25	40
Nitrophilous weed assoc.					
before treatment, autumn, 1974	24	18	8	49	0
after treatment, winter, 1976	0	5	16	4	35
Nassella trichotoma[b] **pasture**					
before treatment, autumn, 1963	79[c]	0	1	4	0
after treatment, autumn, 1973	21[d]	1	3	12	46
Hypericum perforatum[e] **pasture**					
before treatment, autumn, 1972	1	1	6	90[f]	0
after treatment, autumn, 1974	1	1	5	23[f]	61

[a] Campbell (1974c)—mean of 12 herbicide treatments.
[b] Campbell (1974a)—mean of six herbicide treatments.
[c] Mainly *N. trichotoma*.
[d] Campbell, Flemons and Dellow (1975)—mean of four herbicide treatments.
[e] Mainly *H. perforatum*.

TABLE 7. Dry matter production of surface-sown species on the native grass site after application of herbicide, seed and fertilizer compared to production on the adjoining pastures: one where *Trifolium subterranean* and superphosphate had been aerially applied and one where no treatment was imposed.

Treatment	Year 1973/74 Dry Matter	1973/74 C.P.	1974/75 Dry Matter	1974/75 C.P.
	kg/ha	%	kg/ha	%
Herbicide, seed and fertilizer	14 700	21.4	9 200	18.1
T. subterraneum and superphosphate	7 800	11.6	4 100	10.9
Nil	—	—	600	8.0

[a]*M. sativa, T. subterraneum, D. glomerata, P. tuberosa;* C.P. Crude protein.

Production was increased from 0.5 to 10 dry sheep equivalents/ha by replacing the *N. trichotoma* with perennial species (Campbell, 1974a). Similar increases in production would be expected by improving *H. perforatum* pasture. No estimate has been made of increased production due to improving the nitrophilous pasture.

Practical Application

The techniques outlined above have been utilized by landholders using aircraft to apply herbicide, seed and fertilizer in each of the four situations described. Results have been successful, but widespread adoption has been limited because farmers are not familiar with the techniques; they suspect the costs are higher than for cultivation and they are not pressed to develop their hill land. Should the necessity arise for hill land to be more intensively used in N.S.W., the techniques for improvement are available.

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DISCUSSION

Unidentified. What is bloat risk when you have that good a stand of alfalfa?

Dowling. There were two things that I did not mention. This is basically sheep country. The alfalfa seeded down would be aimed primarily at sheep production. There could be problems where cattle were being grazed in these areas. The one thing I did forget to mention was that to get the best out of alfalfa you need to have rotational grazing and the cost of fencing could be quite prohibitive to a lot of the fellows who own this type of land.

J. Winch (Ontario, Canada). Please comment concerning glyphosate having a deleterious effect on establishing legumes.

Dowling. I am not completely familiar with that but evidently this was the first instance of work that showed that glyphosate did have some sort of residual action instead of being completely inactivated

on contact with the soil. Campbell's work showed that glyphosate did interfere with or inhibit germination and establishment of leguminous species. I do not know whether anyone else has found this. Certainly glyphosate has opened up new vistas for this work. The old stock horse that we've used, 2, 2-DPA, while being good, still needs a period between actual herbicide application and the time when seeding can occur and you can get regeneration of some competitive species in the meantime. Glyphosate hopefully will overcome this problem.

R. Blaser (Virginia, USA). I was wondering about this serrated tussock; I would guess that the protein content is low. Suppose you supplied a urea supplement. What might that do by enforcing grazing to get rid of it rather than using herbicide?

Dowling. They tried this in 1964 and it did not work. They tried all sorts of ways of getting around the problem and it appears as though the only way the problem could be overcome was by a direct frontal attack.

22.
Minimum Tillage Establishment of Five Forage Species Using Five Sod-seedling Units and Two Herbicides*

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Many thousands of pasture hectares in the United States are producing forage yields well below potential. In the humid region more than three-fourths of the pasture is located on land too steep for safe conventional tillage operation necessary for complete pasture renovation (USDA, 1971). Sod-seeding (minimum tillage) renovation offers an excellent alternative for improving forage production and quality without the threat of large-scale erosion problems on these areas.

Sod-seeding is not new; the practice and equipment to do the job has been available for over 25 years. Dudley and Wise (1953) reported on equipment and practices for introducing cereals into grass swards to extend the grazing season and improve forage yields. The first commercial sod-seeders of 25 years ago did an excellent job of seeding cereals and other large-seed species into pastures but none was consistently satisfactory for establishing small-seed forages in an undisturbed sod. These seeders failed because of three important reasons: competition from the existing sod was not adequately controlled; seed placement was usually either too shallow or too deep; good seed-soil contact was not always achieved.

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Early research at Maryland concerned with sod-seeding of small-seed legumes centered around modification of existing seeders (Decker *et al.*, 1964). Where competition from the existing vegetation was reduced by removing a narrow, shallow band of sod, excellent stands of small-seed legumes were consistently obtained (Table 1). Best stands were obtained when seeds were drilled into the sod-free furrows with just enough loose soil in the bottom of the furrow for shallow, firm seed coverage. In 1964, a small-plot prototype sod-seeder was compared with conventional pasture renovation and different fertilization programs. One treatment using paraquat in a 15-cm band over the seeded row was also included (Decker *et al.*, 1969). Conventional renovation produced highest yield during the first two years, but by the third season, sod-seeded crownvetch was producing almost twice as much forage as a complete

TABLE 1. Plant numbers and dry matter yields of sod-seeded birdsfoot trefoil, 1960–61

Sod opener	Plant numbers/0.6 m of row: Fall seeding	Plant numbers/0.6 m of row: Spring seeding	G dry matter per 6.1 m of row
Spear	3.6[a] c	1.2 c	3.4 c
Spear + wing	13.8 b	8.0 b	66.3 b
Spear + disc	22.0 a	17.5 a	116.0 a

[a]Numbers within a column followed by the same letter are not different ($P \leq 0.05$).

TABLE 2. Forage yields of bluegrass pasture treated in various ways as affected by fertilizer and sod-seeding treatments

		Lime, phosphorus and potassium					
		Kg N/ha				Sod-seeded crownvetch	
Years	Untreated Sward	0	112	224	Complete renovation[a]	Sod removed	paraquat
	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha
1965	1.39 d[b]	2.08 bcd	3.50 ab	3.88 a	3.99 a	2.48 bc	2.57 bc
1966	0.83 d	1.21 c	3.05 b	4.25 a	4.37 a	3.06 b	3.12 b
1967	1.45 f	3.05 d	4.95 c	6.65 a	2.76 e	5.20 b	5.52 b
Avg.	1.21 e	2.11 d	3.81 b	4.93 a	3.70 bc	3.53 bc	3.84 bc

[a]Seeded with orchardgrass-red clover-ladino clover mixture.
[b]Numbers within a year followed by the same letter are not different ($P \leq 0.05$).

renovation seeded with an orchardgrass-red clover-ladino clover mixture; it required 112 kg N/ha for the undisturbed sward to produce as much forage as the sod-seeded crownvetch treatment (Table 2).

Research at Kentucky (Taylor *et al.*, 1964) produced similar results by employing a powered rotation disc set at an angle to till the desired width of sod (0.6 to 5.7 cm) to a depth of 1.9 cm. The new John Deere Power Seeder was developed from these research findings. (Mention of a company or proprietary product does not constitute a guarantee of warranty by the U.S. Department of Agriculture and does not imply its approval of other products that may be suitable.)

Following World War II, when there was an abundance of low-cost feed grain, the emphasis on pasture research and utilization in the United States greatly declined. However, by the early 1970's, feed grain shortages and skyrocketing price increases placed forages in a more competitive position. The concurrent widespread use of paraquat in no-tillage corn production prompted many researchers to once again look at no-tillage pasture renovation. The wide selection of no-tillage equipment for corn and soybean production opened the possibility of using such equipment for no-tillage pasture renovation. With this in mind, three experiments were started in 1974 to look at different soil tillage and seed placement units, herbicides, and methods of applying herbicide in no-tillage forage establishment.

MATERIALS AND METHODS

The experimental site was located at 38° 19′ north latitude on a uniform east, southeast slope that varied between 5 and 15%. The soil was a Chillum silt loam with a pH of 6.5 and medium levels of both P and K. The area supported a sward of predominantly Kentucky bluegrass (*Poa pratensis*) and timothy (*Phleum pratense*). The entire area was uniformly fertilized each spring with 224 kg/ha of an 0-20-20 fertilizer. In the spring of 1974, three randomized complete block experiments with four replications were started; replications for each experiment were at right angles to slope.

EXPERIMENT I

We compared the basic John Deere Grassland Drill of the 1950s (John Deere and Co., Moline, Ill.) using paraquat (1, 1′-demethyl-4-4′ bipyridinum ion) at 0.56 kg/ha and glyphosate (N-(phosphonomethyl) glycene) at 1.68 kg/ha banded over each row at seeding with (a) the same seeder equipped with a concave disc to remove a 15-cm strip of sod just ahead of the spear seeding unit, (b) a wide flute soil opener-double disc seeder, (c) a narrow flute soil opener-double disc seeder, (d) a deep ripple soil opener-double disc seeder, and (e) a wide flute soil opener with only the presswheel to place the seed. Herbicides were used on treatments b through e. Chesapeake red clover (*Trifolium pratense*), Empire birdsfoot trefoil (*Lotus corniculatus*), and Penngift crownvetch (*Coronilla varia*) were seeded.

EXPERIMENT II

We seeded the red clover, trefoil, and crownvetch into the bluegrass-timothy sod using the wide flute-double disc unit. Paraquat was applied at seeding in 15-cm bands over the rows at the rate of 0.28, 0.56, and 1.12 kg/ha.

EXPERIMENT III

We compared the wide flute-double disc unit to the Zip seeder (Midland Manufacturing Co., Inc., Electric Mills, Miss.). Paraquat at 0.56 and glyphosate at 1.68 kg/ha were applied in a broadcast application over the entire plot. The same herbicide rate per unit area was applied in a 10-cm band (approximately one-half of the plot area) over the seeded row. Red

TABLE 3. Sod suppression and stand rating of sod-seeded red clover (seeded March 26, 1974)

			Paraquat			Glyphosate
Concave disc spear seeder	Straight colter spear seeder	Deep ripple disc seeder	Narrow flute disc seeder	Wide flute disc seeder	Wide flute presswheel only	Wide flute disc seeder
			Sod Suppression[a] (5-7-74)			
5.0 a[b]	2.8 c	2.5 c	2.8 c	2.6 c	3.2 b	5.0 a
			Stand Rating[c] (6-27-74)			
2.2 bcd	2.5 bc	2.5 bc	2.0 c	3.2 b	2.0 c	4.5 a
			Stand Rating[c] (8-5-74)			
2.2 d	2.2 d	3.2 bc	3.0 cd	4.0 ab	2.0 d	4.8 a

[a]1 = none; 5 = complete suppression.
[b]Numbers within a single harvest followed by the same letter are not different (P ≤ 0.05).
[c]1 = poor; 5 = excellent stands.

TABLE 4. Effects of soil tillage and seed placement units on total forage yields of red clover sod-seeded in a Kentucky bluegrass-timothy pasture

					Paraquat			Glyphosate
Harvests	Check	Concave disc spear seeder	Straight colter spear seeder	Deep ripple disc seeder	Narrow flute disc seeder	Wide flute disc seeder	Wide flute presswheel only	Wide flute disc seeder
	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha
Last 1974	1.57 e[a]	2.15 d	2.29 c	2.35 c	2.47 ab	2.82 a	2.44 ab	2.69 a
First 1975	2.02 c	3.72 a	3.00 b	3.30 ab	3.14 ab	3.30 ab	3.38 ab	3.41 ab
Last 1975	2.89 a	2.11 a	2.47 a	2.20 a	2.42 a	2.78 a	2.20 a	2.44 a

[a]Numbers within a single harvest followed by the same letter are not different (P ≤ 0.05).

clover, trefoil, crownvetch, Team alfalfa (*Medicago sativa*), and Ky-31 tall fescue (*Festuca arundinacea*) were evaluated.

Data collected for each experiment consisted of plot ratings on the degree of sod suppression, stand ratings as a measure of initial establishment, and forage yields (seeded species, original grass, weeds, and total). Data were subjected to statistical analysis.

RESULTS

Experiment I

Initial red clover stands were fair to excellent on all plots, whereas those of trefoil and crownvetch were poor. For this reason sod suppression and stand ratings are presented only for plots seeded with red clover (Table 3). Sod suppression was more complete for glyphosate than for paraquat, and initial stand ratings were also higher with glyphosate. Differences in initial stands due to mechanical seeding units were small. There appeared, however, to be a slight advantage for the wide flute-disc seeder unit, but differences were not significant (P≤0.05).

Total forage yields are given in Table 4. In 1974, all sod-seeded treatments were significantly more productive than the check. The wide flute-double disc unit had the highest yield but was not different from the narrow flute or the wide flute with presswheel only. The deep ripple and straight colter treatments were less productive (≤0.05) than the fluted openers but were more productive than the treatment with the sod strip removed. By the spring of 1975, differences between the sod-seeded treatments had largely disappeared. By the fall of 1975, when most of the red clover plants had died off, there were not significant yield differences even though the check treatment was consistently most productive.

The sod seeded red clover plots in Experiment I were more productive (P≤0.05) during the year of establishment than either trefoil or crownvetch (Table 5); these differences were due primarily to the legume component, but increased grass yields were also associated with the better legume stands. Weed yields were similar for all treatments. There was no difference between paraquat and glyphosate in either legume or total yield values.

TABLE 5. Botanical composition of three sod-seeded legumes as affected by herbicides

Botanical composition	Paraquat Red clover	Paraquat Crown-vetch	Paraquat Trefoil	Glyphosate Red clover	Glyphosate Crown-vetch	Glyphosate Trefoil
	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha
Legume	1.10 a[a]	0.04 b	0.07 b	1.08 a	0.09 b	0.09 b
Weeds	0.18 a	0.20 a	0.22 a	0.22 a	0.22 a	0.22 a
Total[b]	2.82 a	1.93 b	1.93 b	2.69 a	1.91 b	1.68 b

[a]Numbers within each yield component followed by the same number are not different (P ≤ 0.05).
[b]Total includes grass, legume, and weed yields.

TABLE 6. Sod suppression within herbicide band and stand rating of three-seeded legumes as influenced by paraquat rate

Paraquat (kg/ha)	Sod suppression[a] 5-27-74	Stand rating[b] 6-27-76	Stand rating[b] 8-5-76
	Red clover		
0.28	1.5 cd[c]	2.2 abc	2.0 b
0.56	2.2 bc	2.5 ab	3.2 a
1.12	4.8 a	3.5 a	4.0 a
	Crownvetch		
0.28	1.0 d	1.0 c	1.0 c
0.56	2.2 bc	2.2 abc	1.0 c
1.12	4.8 a	1.5 bc	1.0 c
	Trefoil		
0.28	1.0 d	1.0 c	1.0 c
0.56	2.8 b	1.5 bc	1.0 c
1.12	4.8 a	1.5 bc	1.2 c

[a]1 = poor; 5 = complete.
[b]1 = poor; 5 = excellent.
[c]Numbers within each column followed by the same letter are not different (P ≤ 0.05).

Experiment II

The effects of paraquat rate on sod suppression and initial stand establishment can be seen in Table 6. The degree of sod kill increased (P≤0.05) with increased paraquat rate. The kill was nearly complete at 1.12 kg/ha. At 0.28 kg, the sod was only slightly suppressed, and initial stands were correspondingly lower; this was especially true for red clover.

There was a marked shift in botanical composition of the swards from the fall of 1974 through the spring of 1976. This was true for all three experiments, but we harvested only Experiment II in 1976 to document these effects. As was true in the first experiment, differences in weed yields were small, and the major effect on yields was attributed to the legume component. Legume and total yield values are shown in Table 7. In 1974, red clover was about half the total forage yield, whereas the other two species made up less than 5%. By the end of 1975, however, red clover had dropped to 20% of the total forage yield, whereas, crownvetch had increased to more than 40% and trefoil to over 30%. In the spring of 1976, crownvetch made up more than 50% of the total yield with trefoil being almost as high.

Experiment III

Species responses were similar to those found in the other two studies, so not all of the data from this study are presented. Alfalfa and tall fescue were not included in the first two studies so their responses are compared here with red clover, which was included in all three (Table 8). In 1974, total yield was higher (P≤0.05) for the red clover. Alfalfa seeded with glyphosate was least productive. The yield of both red clover and alfalfa was higher (P≤0.05) for paraquat-treated plots than for those receiving glyphosate. Tall fescue made up less than 3% of the total yield in 1974, but, by the last harvest in 1975, it had increased to 37% and 52% where seeded with paraquat and glyphosate, respectively. Red clover was still superior to alfalfa, and the paraquat treatment had the highest dry matter yield.

The wide flute-double disc seeder was common to all three experiments, so this unit was compared with the commercially available Zip seeder (Table 9). Total yields were similar in 1974 for both seeders and both herbicides. However, there were greater clover yields in the paraquat-treated plots (94 vs 53%, P≤0.05). There was no difference between seeders in either total or legume yields. By the end of 1975 there was no difference between seeders or herbicides and the study was discontinued.

Banded vs. broadcast application of herbicides were compared only with the Zip seeder; those data are given in Table 10 for red clover only. The tall fescue stands were too weak and erratic for meaningful comparisons. There were no differences in total yield between banded and broadcast treatments for either year. However, the amount of red clover was greater (P≤0.05) in 1974 on the broadcast plots; there was no difference in 1975. Changes in weed yields really tell the story; in 1974 there was no statistical

TABLE 7. Effect of paraquat rate on legume component and total yield of three sod-seeded legumes

Paraquat (kg/ha)	Legume yield: Red clover	Legume yield: Crownvetch	Legume yield: Trefoil	Total yield[a]: Red clover	Total yield[a]: Crownvetch	Total yield[a]: Trefoil
	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha
			Last Harvest 1974			
0.28	0.54 b[b]	0.04 c	0.02 c	1.68 ab	1.23 cd	1.08 cd
0.56	0.60 ab	0.04 c	0.04 c	1.79 a	1.30 cd	1.37 bc
1.12	0.72 a	0.04 c	0.09 c	1.95 a	1.14 cd	1.21 cd
			Last Harvest 1975			
0.28	0.42 de	1.23 ab	0.92 bc	2.17 de	3.05 ab	3.05 ab
0.56	0.31 e	1.50 a	0.83 c	2.17 de	3.32 a	2.60 bcd
1.12	0.40 de	1.10 bc	0.85 bc	1.86 e	2.74 bc	2.53 cd
			First Harvest 1976			
0.28	0.40 f	1.46 bc	1.39 bcd	1.91 cd	2.91 b	2.91 b
0.56	0.45 f	1.70 bc	1.26 cd	1.95 cd	3.12 b	2.62 bc
1.12	0.58 f	2.22 a	1.46 bc	1.50 d	4.10 a	3.12 b

[a]Includes legume, grass, and weed components.
[b]Numbers within years and yield component followed by the same letter are not different ($P \leq 0.05$).

TABLE 8. Effect of broadcast herbicides at seeding on total yield and seeded component of three sod-seeded forages using the Zip seeder

Species	Dry matter yield (1974): Seeded species[a]: Paraquat	Seeded species: Glyphosate	Total: Paraquat	Total: Glyphosate	Dry matter yield (1975): Seeded species: Paraquat	Seeded species: Glyphosate	Total: Paraquat	Total: Glyphosate
	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha
Red Clover	3.09 a	1.52 b	3.25 a	2.78 ab	2.42 a	2.24 a	3.63 a	3.68 a
Alfalfa	1.01 bc	0.56 c	2.11 c	1.73 c	2.58 a	1.12 b	3.99 a	2.74 b
Tall fescue	0.04 d	0.02 d	1.95 c	2.38 bc	0.74 b	0.94 b	2.00 c	1.79 c

[a]Values within the seeded or total columns for a particular year followed by the same letter are not different ($P \leq 0.05$).

TABLE 9. Comparison of the Zip seeder with the wide flute-disc seeder unit with broadcast herbicides

Year	Red clover yields: Zip seeder: Paraquat	Zip seeder: Glyphosate	Wide flute disc seeder: Paraquat	Wide flute disc seeder: Glyphosate	Total yields[a]: Zip seeder: Paraquat	Zip seeder: Glyphosate	Wide flute disc seeder: Paraquat	Wide flute disc seeder: Glyphosate
	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha
1974	3.09 a[b]	1.52 b	3.27 a	1.64 b	3.25 a	2.78 a	3.52 a	3.23 a
1975	2.42 a	2.24 a	2.64 a	1.93 a	3.63 a	3.68 a	3.65 a	3.34 a

[a]Includes clover, grass, and weed components.
[b]Numbers followed by the same letter for either red clover or total within a single year are not different ($P \leq 0.05$).

TABLE 10. Effects of broadcast vs. banded paraquat on yields of sod-seeded red clover plots using the Zip seeder

Yield component	Dry matter yields (1974)		Dry matter yields (1975)	
	Banded	Broadcast	Banded	Broadcast
	t/ha	t/ha	t/ha	t/ha
Red clover	1.30 b[a]	3.09 a	1.84 a	2.42 a
Weeds	0.07 a	0.16 a	0.42 b	1.23 a
Total[b]	3.12 a	3.25 a	3.56 a	3.63 a

[a]Numbers within a year and yield component followed by the same number are not different ($P \leq 0.05$).
[b]Total yield includes clover, grass, and weed components.

difference in weed yield between banded and broadcast even though the banded plots had fewer weeds. By 1975, however, the weeds in the broadcast plots had increased to 34%, whereas in the banded plots they made up only 12%.

DISCUSSION AND SUMMARY

The type of seeder per se did not always appear to be the determinant of success of failure. The type and condition of the sod and the type of soil and climatic conditions during establishment play an equally important role. The wide flute soil opener-double disc seeder unit did, however, appear to be slightly superior. As pointed out by Murphy and Arney (1939) and Williams (1956), shallow seed placement is a must for successful forage stands and the double disc with depth bands does an excellent job of seed placement.

Nothing will do more to ensure successful forage stands than a light uniform mulch (Moore, 1943), and the paraquat-treated sod produces an excellent mulch.

Based on these studies a complete kill of the existing sod is not necessary; it need only be suppressed until the new seedlings are established. When the sod was completely suppressed by broadcast application, severe weed invasion often occurred. Management of the sod-seeded pasture following establishment is just as critical as the seeding itself. Band application of herbicides appears to have two main advantages over broadcasting; first, the untreated sod serves as a companion crop controlling early weed growth between the sod-seeded rows, and second, the seeded legumes stimulate the grass, producing overall yield increases.

These studies clearly demonstrated a wide range in species performance. Red clover is relatively easy to establish and provides significant yield increases soon after seeding. Crownvetch and trefoil, on the other hand, are slower to establish but stands and yield contributions tend to increase with time. A combination of species like red clover and crownvetch should provide early yield improvement with long-lasting effects. Alternate row seeding of such species may be the answer. Unless a more persistent legume is seeded with red clover, severe weed invasion is likely to occur, as the red clover is lost. An alternative would be to seed red clover about every two years.

In predominantly bluegrass-timothy sods, paraquat at 0.56 kg/ha provides adequate vegetation control. However, with more vigorous species higher rates of paraquat or a herbicide like glyphosate may be needed.

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DISCUSSION

G. Jung (Pennsylvania, USA). A critical point of your summary is whether the lack of persistence of red clover was the function of management or of disease. If you had used the more improved varieties, out of Kentucky and Wisconsin, would that third-year red clover yield be much higher than you had in this set of data you showed us?

Decker. No. Very definitely, especially those varieties from Wisconsin, they would perform much less well than Chesapeake. I do not think you can find a variety that would perform as well in our situation. We have done some work with the new variety Kenstar; perhaps it is a little more tolerant, more persistent, than Chesapeake. There is a complex of diseases and insects, but nothing that we have been

able to do has maintained red clover of any variety beyond the third year. This started in 1974 and 1975 and we took yields in 1976 but after that first yield in 1976 they were completely gone. These were harvested four times during the year and this may be a little severe management for them. If we had managed it as a hay crop, perhaps we would have been able to maintain it.

T. Taylor (Kentucky, USA). We have a similar experiment where we did not use herbicide and where we used these two. And our experiences, similar to yours, have been simply this: without herbicide we have better grass and clover under our management system, especially bluegrass. When we kill too much of this grass, the red clover, in particular, is very suppressive on the grass, especially tall fescue. It is more suppressive to tall fescue than it is to Kentucky bluegrass. Our experience has been the same as yours about establishing alfalfa. However, we believe that if we seeded the alfalfa later in the season we might be able to establish it in these sods. We have done this already and are getting better stands by seeding later.

23.
Pasture Renovation with Alternate Row Sod-seeding of Different Legume Species*

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According to Hodgson (1974), 2/3 of the feed units for dairy cattle and 3/4 of the feed units for beef come from forage; some 45 million beef cows presently obtain over 95% of their feed from forage. Per capita beef consumption in the United States increased from 28 to over 52 kg between 1952 and 1972. While this increase has leveled somewhat, the demand for red meat continues to increase (USDA, 1973). With the increasing world demand for feed grains, the livestock industry must rely even more heavily on forages for an economic feed source. In the future, cash crops will require an even higher percentage of the prime agricultural land if world food demands are to be met. Therefore forage to feed the increasing livestock numbers will have to come largely from marginal land.

An alarming trend in the Northeast and throughout much of the humid eastern half of the U.S. has been the abandonment of land previously held in pasture (USDA, 1965). Millions of hectares of mismanaged pasture and crop lands have already reverted to woodland and brush. Much of the land that has fallen into disuse is well suited to the production of forage crops for livestock but could not be safely cultivated intensively. Much of the permanent pasture land (primarily bluegrass) still in use does not produce close to potential (Wedin *et al.*, 1967). Research at Maryland and Virginia (Blaser *et al.*, 1956; Decker, 1959; Ronningen *et al.*, 1955) demonstrated that bluegrass could produce nearly as much beef per ha as the taller growing species such as orchardgrass-ladino clover. However, 75 to 80% of bluegrass pasturage is produced by the end of June, so systems to utilize such forage when available are critical.

The percent of legume (primarily white clover) in most permanent pastures greatly affects the yield and quality of forage produced. Adequate lime, P and K will usually increase the legume component and improve yields, but clover stands are often erratic in spite of a good fertility program. Wedin *et al.* (1967) nearly tripled beef gains by renovating bluegrass-white clover pastures and seeding Empire birdsfoot trefoil. The successful introduction of legumes into a grass-dominant sod has been reported (Decker *et al.*, 1964, 1969; Taylor *et al.*, 1969). After three years, sod-seeded crownvetch in the Maryland study produced twice as much clipped forage as conventionally renovated pastures seeded to an orchardgrass-ladino clover-red clover mixture.

Sod-seeding studies at Maryland demonstrated a wide range in rate of establishment among various legumes. Red clover was the easiest to establish using sod-seeding techniques but seldom lasted beyond the second year, especially under pasture-type defoliation. Crownvetch, on the other hand, was slower

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to establish but stands improved with time. A logical choice, then, would seem to be a combination of these two widely different species. The objectives of the present study were to improve the forage production of abandoned pasture land by the use of sod-seeding and to compare combinations of rapid and slow establishing species for immediate and long-lasting pasture improvement.

MATERIALS AND METHODS

The experimental site was located at 38° 59′ north latitude. The soils were primarily Sassafras sandy loams with isolated area of Christiana fine sandy loam. At the start of the study, the pH varied from 7.0 to 7.7 and the P and K levels varied from low to medium. The area was fertilized with 392 kg/ha of an 0-15-30 fertilizer in the fall of 1974 and again in the spring of 1976. The area had been seeded to an orchardgrass pasture during the 1960s but was unused for approximately ten years and allowed to revert to bluegrass, herbaceous weeds and woody species. During the late summer of 1974 the area was clipped with a heavy-duty rotary mower. Regrowth following clipping and excess trash were removed with a flail forage harvester. The area was then divided into 20, 0.61-ha paddocks. These were then blocked into "uniform" groups of three according to physical location, soil condition and vegetative cover. Three of these groups (nine paddocks) were combined to make one replication. Three pasture treatments were randomly assigned within each uniform group of three paddocks. Pastures were grazed in a three-paddock rotational system. The experimental design was a randomized split plot with two replications. The whole plots were grazing cycles (three uniform paddocks), and sub-plots were pasture treatments. Pasture treatments were: (A) weed and brush removal plus fertilization, (B) weed and brush removal plus fertilization and alternate row sod-seeding of a mixture of Chesapeake red clover (*Trifolium pratense*) and certified ladino clover (*T. repens*) with Penngift crownvetch (*Coronilla varia*), and (C) weed and brush removal plus fertilization and alternate row sod-seeding of a mixture of red clover and ladino clover with Spredor alfalfa (*Medicago sativa*).

The sod seeding was done with a Zip seeder (Midland Manufacturing Co., Electric Mills, Miss.) equipped with a band spraying attachment to apply a 10- to 15-cm band of paraquat (1, 1′-dimethyl-4-4′ bipyridinum ion) at the rate of 0.56 kg/ha over each row at seeding. The Zip seeder was initially used to seed cereals into dormant bermudagrass sods. This particular machine was equipped with a fluted-feed seed box for seeding small-seeded legumes.

The plantings were scheduled for late August, but extended rains delayed trash removal and forced a delay of approximately one month; even then the soil was too wet for ideal machine operation, especially in paddocks where surface trash was not adequately removed. Adequate stands were obtained on all paddocks even though many of the seedlings were small going into the winter.

Animals used in the grazing study were dairy heifers and steers. In 1975, two heifers and two steers were used as testers on each treatment, but animal sizes were quite variable and no attempt was made to measure differences between animal size or type. In 1976, two heifers (approximately 245 kg) and two light steers (approximately 200 kg) were assigned as testers to each treatment. Additional light steers were used as supplementary grazers when needed to utilize excess forage growth. One heavy steer (approximately 340 kg), from a group which had been on the 1975 study and overwintered on a maintenance diet, was also added to each experimental pasture to remain through the flush spring growth and then marketed.

Assignment of the tester animals to the pasture treatments was accomplished by dividing the animals into six groups to give approximately the same total liveweight; one light and one heavy animal of each sex was assigned to each group. The groups were then arbitrarily assigned to replications and then randomly assigned to pasture treatments within each replication. In 1976, heavy steers from the 1975 season were also assigned at random to pasture treatments within each replication. Average daily gains were calculated on tester animals. Liveweight gains of testers plus total liveweight of testers and grazers were used to calculate gains per ha, animal grazing days and pasture carrying capacity.

RESULTS

Daily animal gains were significantly higher on the sod-seeded pastures (Table 1). There was,

TABLE 1. Average daily gains, carrying capacities and total gains per ha for 1975

Pasture treatment	Animal gains/day	Pasture[a] carrying capacity	Liveweight gains/ha
	Kg	No.	Kg
(A) Check	0.33 b[b]	6.18 c	69.7 b
(B) Sod-seeded crownvetch, red clover and ladino	0.59 a	9.07 a	186.7 a
(C) Sod-seeded alfalfa, red clover and ladino	0.64 a	7.92 b	155.9 a

[a]Number of 318 kg animal units maintained per ha.
[b]Values within a column with the same letter are not significantly different at the 0.05% level according to Duncan's multiple range test.

however, no real difference between the alfalfa and crownvetch pastures. The carrying capacity of the pastures was significantly increased by the sod-seeded legumes. The highest carrying capacity was obtained with crownvetch followed by the alfalfa and then the check pastures. During the 1975 grazing season, red clover was the major sod-seeded legume present and the slightly better performance of the crownvetch pasture was due primarily to a better red clover stand rather than to differences between crownvetch and alfalfa. Total liveweight gain per ha was significantly increased by the sod-seeded legumes. The crownvetch pastures with the best red clover stands produced 30 kg more gain than the alfalfa pastures but this difference was not significant at P = 0.05.

Forage available for grazing on the sod-seeded pastures (treatments B and C) was judged to be substantially higher in quality than that available on the check pasture (treatment A) because of the high clover percentage and lower weed population. This higher quality was reflected in animal condition. At the end of the grazing season all test animals were independently graded by four individuals. Condition of both heifers and steers on the sod-seeded pastures was consistently higher than on the check pastures. The higher amount of red clover in treatment B was associated with slightly higher condition.

TABLE 2. Animal condition at the end of the 1975 grazing season

Pasture Treatment	Animal Type: Heifers	Steers	Average
(A) Check	3.1*	2.7	2.9 ± .34
(B) Sod-seeded crownvetch, red clover and ladino	3.6	3.6	3.6 ± .34
(C) Sod-seeded alfalfa, red clover and ladino	3.3	3.2	3.3 ± .34
Average	3.3 ± .15	3.2 ± .15	

*Values are averages of four animals independently rated by four individuals (1 = poor; 2 = fair; 3 = good; 4 = very good; and 5 = excellent—steers, over-conditioned—heifers).

Botanical composition of the pastures was determined approximately three weeks after the animals were removed at the end of the 1975 grazing season. A second determination was made in early April, 1976, before grazing started (Table 3). In the check pastures, the legume component was essentially zero in the fall of 1975 and increased to only 1% by the following spring; the legume was primarily white clover. On some of the check paddocks, however, significant amounts of volunteer small hop clover (*Trifolium agrarium*) and common vetch (*Vicia villosa*) appeared by mid-May along with a marked increase in white clover (*Trifolium repens*). The amounts of alfalfa, crownvetch, and white clover present in the fall of 1975 were small and red clover was the major legume present in the sod-seeded paddocks. If forage yield components had been determined, well over 50% would have been red clover in many of the sod-seeded paddocks. There was an increase in red clover, crownvetch, and white clover from the fall of 1975 to the spring of 1976. By mid-June, 1976, the white clover, which had accounted for only a small percentage of the forage earlier, was now a major legume in many sod-seeded paddocks. The percent of grass changed very little over the winter except on the check paddocks where there was a small increase; weeds generally decreased on all treatments.

TABLE 3. Effect of sod-seeding on the vegetation components of the pasture sward

Pasture components	Percent ground cover* Treatment A Fall 1975	Treatment A Spring 1976	Treatment B Fall 1975	Treatment B Spring 1976	Treatment C Fall 1975	Treatment C Spring 1976
	Percent					
Crownvetch			2	3		
Alfalfa					1	1
Red clover			18	27	7	13
White clover	<1	1	4	10	3	7
Grass	53	70	53	40	58	58
Other	46	29	23	20	31	21

*Each value is the average of 36 randomly selected 60-sq. cm quadrats, six per paddock.

The grazing season in 1976 started on April 20 and animal performance data through June 10 are presented in Table 4. This date was selected because it was near the end of the heavy spring flush of growth and the heavy steers were removed from the study at this time.

Total carrying capacities of these pastures followed a similar pattern to that observed in 1975 with the sod-seeded pastures carrying significantly more animals per ha than the check pastures.

Liveweight gain of the heifers was essentially the same on all treatments; this is not surprising since the forage on all treatments was young and succulent and even though there was more clover on the sod-seeded treatments, enough grazers were put on these pastures so that forage availability for any one animal was similar for all treatments. Even though animals on the sod-seeded pastures tended to gain more rapidly than those on control pastures, there were no statistical differences among pastures for daily gain of either the light or heavy steers.

TABLE 4. Average daily gains, pasture carrying capacity, and total liveweight gain per ha, April 20 to June 10, 1976

Pasture treatment	Average daily gain (kg) Heifers	Light steers	Heavy steers	Avg.	Pasture[a] carrying capacity	Kg gain/ha Heifers	Small steers	Heavy steers	Total
Check	1.06 a[b]	0.89 a	1.10 a	1.02 a	10.69 b	59.6 a	50.0 b	22.2 b	117.8 b
Crownvetch	1.09 a	1.12 a	1.31 a	1.17 a	14.53 a	61.2 a	103.2 a	49.6 a	191.1 a
Alfalfa	1.06 a	1.03 a	1.72 a	1.27 a	13.70 a	59.4 a	87.6 a	48.3 a	174.6 a

[a]Number of 318 kg animal units maintained per ha.
[b]Values within a column with the same letter are not significantly different at the 0.05% level according to Duncan's multiple range test.

An attempt was made to stock pastures so that all had approximately the same grazing pressure. Small differences in daily animal gains among pasture treatments in 1976 tend to support the thesis that comparable grazing pressures were achieved. Even though daily gains were not significantly different, the higher rates were always associated with the sod-seeded pastures. Pasture growth during late May, 1976, was heavy and not enough animals were available to keep it grazed down. On May 22, all treatments in cycle B were harvested as silage. Yields were 0.21, 0.96, and 0.58 MT of dry matter per ha for treatments A, B and C, respectively. While these yields represent only one third of the paddocks, they are considered representative of differences throughout the study. The sod-seeded pastures usually had three to four times as much available forage and because of the higher legume contents it was also judged to be higher in quality. Because of these higher yields and improved forage quality, pasture carrying capacities and liveweight gains per ha were significantly higher on the sod-seeded pastures.

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DISCUSSION

K. O'Connor (New Zealand). Do you have reason to believe that the increased carrying capacity of your improved pastures would have paid for the treatment?

Decker. I think it might. You are not going to make a great deal of money, and I think this would depend on many situations, but I think it is going to be a borderline case. Actually, about all the expense here is the price of the seed and the time it takes you to go over the field once. Now, if you have to use some of these new seeders, like the Betteson, which is around $9,000, or the John Deere, which is around $6,000, you would never make it. This is why we think you have to combine this with a no-till seeder that you use to put in corn and soybeans or some cheap method of putting it in. I do not think you need a particularly sophisticated sod seeder for putting in pastures. I think most of our sod seeders are over-engineered.

24.
Herbage Variety Evaluation Under Hill and Upland Conditions in Wales

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The hills and uplands of Wales cover nearly 1 million ha (56% of the agricultural land) and support 23% of the United Kingdom ewe flock and 8.5% of all beef cows (Ministry of Agriculture, Fisheries and Food, 1976). High overall stocking rates—more than 4 sheep and 0.2 beef cows per ha in the drier eastern counties—are the result of widespread pasture improvement. In the last 25 years over 100 000 ha of rough grazing land (*Pteridium, Ulex, Agrostis / Festuca / Nardus* and *Calluna* communities) have been plowed and reseeded with perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). Stock numbers have increased by 250%.

Many farms, however, continue to suffer from socioeconomic problems. Net incomes are lower and more subject to fluctuation than on lowland dairy and cropping farms (Jones, 1973). Grassland improvement leads to more consistent profitability and the extension of its benefits is essential. Further plowing of drier soils is limited by slope and rock outcrops. The remaining 0.6 million ha of native grassland mainly consists of unproductive *Molinia, Nardus, Trichophorum, Eriophorum* and *Sphagnum* growing on very acid (pH 4.0–4.5) organic soils at higher altitudes (300–600 m) with annual precipitation of 1 500–3 000 mm. At least 25% of this area could be improved by surface-seeding techniques with considerable benefit in stock-carrying capacity and in individual animal performance (Munro, 1976).

A major problem has been the low persistence of ryegrass and clover on wet land, leading to rapid sward deterioration and concurrent decline in livestock production (Ellison *et al.*, 1955). The varieties used hitherto are of lowland origin, bred for maximum production under high fertility and strict management. Since 1961, the Welsh Plant Breeding Station has been studying the potential of alternative species and the need for special purpose varieties. Simultaneous research is taking place on the soil-plant-animal ecosystem (Munro *et al.*, 1973).

PRELIMINARY SCREENING OF SPECIES AND VARIETIES

Three test sites with contrasting climatic and soil conditions were used from 1961–66. Subsequent evaluation has taken place at the Pant-y-dŵr hill centre on a range of soils (Table 1).

Observations cover a total of 150 varieties of 19 grass and 6 legume species of European, North American and Mediterranean origin (Table 2) over a period of 15 years including the severe winters of the 1960's and more recent mild winters and dry summers (Fig. 1).

Varieties were sown broadcast after plowing or surface cultivation in small plots (generally 2.7 m by 1.5 m) with four replicates. Ground limestone (7.5 t/ha) and an initial dressing of fertilizer (400 kg/ha of 20 N : 10 P_2O_5 : 10 K_2O compound) were given prior to sowing, followed by annual maintenance dressings. S.184 white clover (2 kg/ha) was included in the grass plots and S.48 timothy (*Phleum pratense*) in the legume plots (8 kg/ha). Swards were grazed at approximately monthly intervals after sampling or recording.

Sowings took place at Syfydrin and Pwllpeiran in 1961 and at Blaenmyherin in 1962, and further sowing of a limited range of species was carried

TABLE 1. Details of test centers

Center	Altitude (m)	Annual Precipitation (mm)	Temperature Mean Screen (°C)	Wind (m/s)	Soils
Syfydrin	335	1 800	7.9	2.9	Stagnopodzol
Pwllpeiran	397	1 700	—	—	Brown earth
Blaenmyherin	488	2 200	7.4	5.8	Deep peat
Pant-y-Dŵr	305	1 100	7.7	3.4	Brown earth and Stagnogley

TABLE 2. Species and varieties of grasses and legumes tested under hill conditions, 1961–75

Species	Variety	Origin*	Species	Variety	Origin	Species	Variety	Origin
GRASSES								
Agrostis tenuis	Saboval	GB	*Glyceria fluitans*		GB	*Poa pratensis*	S.63	GB
	Br 616	GB	*Holcus lanatus*	Commercial	GB		Commercial	CA
	Commercial	NZ		9 lines	GB		Delta	CA
	Enate	NL	*Lolium multiflorum*	S.22	GB		Fylking	SE
	Holfior	NL		Westerwolds	NL		Merion	US
	Tracenta	NL	L. (*perenne x multiflorum*)	Manawa	NZ		Newport	US
Alopecurus pratensis	S.55	GB	*L. perenne*	S.23	GB		Park	US
Anthoxanthum odoratum	Bs 2811	GB		S.24	GB		1 line	GB
Bromus unioloides	Commercial	NZ		S.101	GB		7 lines	US
Cynosurus cristatus	Commercial	NZ		S.321	GB	*P. trivialis*	Commercial	DK
	Credo	NL		Ba 6280	GB		Trifolium	DK
Dactylis glomerata	S.37	GB		Ba 6736	GB			
	S.143	GB		Irish	GB			
	S.345	GB		Glasnevin	IE			
	Bc 4651	GB		Melle	BE	LEGUMES		
	Commercial	DK		N.F.G.	DE	*Lotus corniculatus*		GB
	Ferdia	IE		Norlea	CA	*L. uliginosus*		GB
	Germinal	FR		Ruanui	NZ	*Medicago sativa*	S.205	GB
	Latar	US		Semperweide	NL	*Trifolium hybridum*	Commercial	CA
	N.F.G.	DE		Steinacher	DE	*T. pratense*	S.123	GB
Festuca arundinacea	S.170	GB		Viktoria	DK		S.151	GB
	4 lines	GB		Viris	SE		Norseman	GB
F. pratensis	S.53	GB	*Phalaris arundinacea*	3 lines	GB		Aa 8	GB
	S.215	GB	*Phleum bertolonii*	S.50	GB		Hungaropoly	HU
	Løken	NO	*P. pratense*	S.48	GB	*T. repens*	S.100	GB
	Minner	SE		S.51	GB		S.184	GB
	N.F.G.	DE		S.352	GB		Sabeda	GB
	Trifolium	DK		Scots	GB		Ac 7	GB
F. rubra	S.59	GB		Heidimij	NL		Ac 19	GB
	Novorubra	NL		King	NL		Huia	NZ
	31 O.E.C.D.			N.F.G.	DE		Kivi	SE
	Varieties			Topas	DK		Morso	SE

*New International Code.

out at Pant-y-dŵr in 1966 and 1971. Special attention was paid to the following attributes:

Establishment Vigor

Rapid establishment is crucial in overcoming competition from regenerating native and volunteer species and in reducing the incidence of frost heaving. Slow seedling development was the principal factor in the poor performance of S.170 *Festuca arundinacea*, *Phalaris arundinacea*, *Medicago sativa*, *Trifolium pratense* and the *Lotus* varieties tested (Munro and Hughes, 1968).

Winter Hardiness

This is an essential attribute, particularly if long-term climatic trends are towards colder winters. Appreciable winter-kill was observed in 1961–62, and 1962–63, and especially in 1968–69 when exceptionally mild, wet conditions in autumn and January were followed by severe cold (lowest February screen minimum at Pant-y-dŵr was −14.5° C). In 1961–62, little damage was noted at Aberystwyth (30 m), but tiller and plant loss was severe at Syfydrin, particularly in *Dactylis glomerata*, *Lolium multiflorum* and two synthetic *Festuca arundinacea* varieties of North African origin (Table 3). Subsequent spring production was negligible in many cases. Within perennial ryegrass, the early varieties, e.g., S.24 and New Zealand, were affected more than late varieties of the S.23 or Melle type. Identical results were achieved in 1962–63 at Blaenmyherin (Hughes and Munro, 1964) and in addition to the above species *Holcus lanatus* and *Poa trivialis* suffered severe winter-kill.

Growth Rhythm

Particular emphasis is placed on production in early spring (April–May)—the most critical period

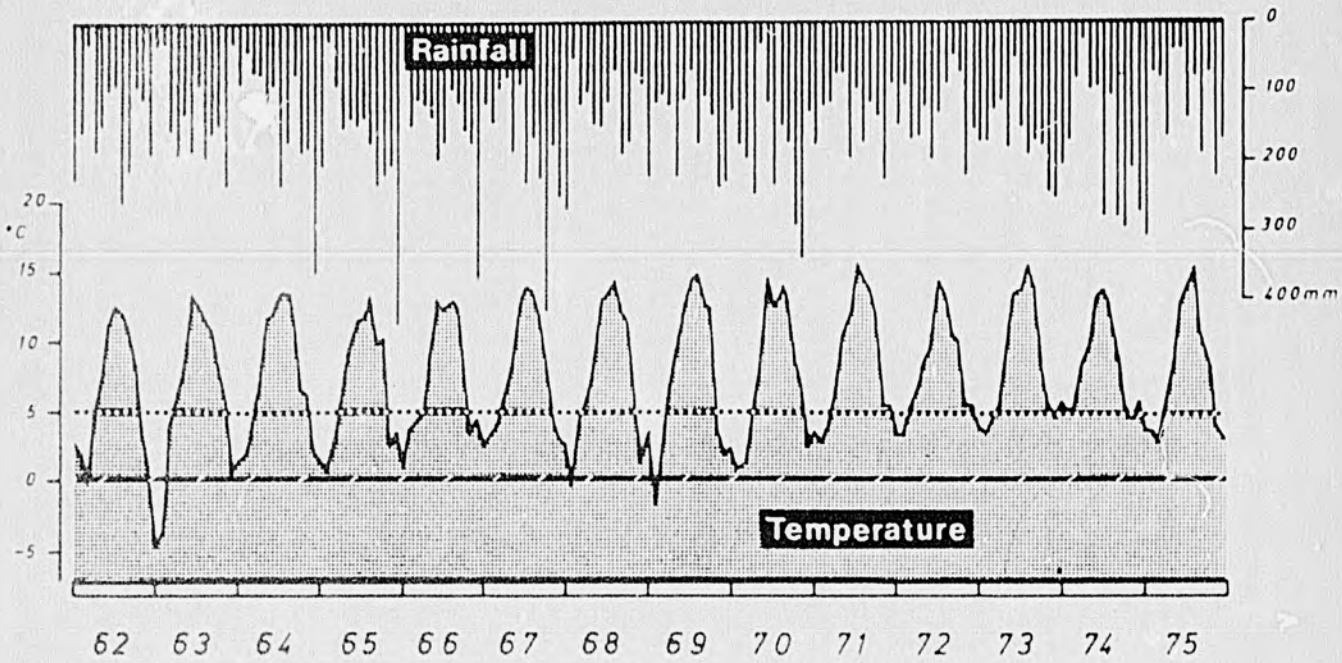

Figure 1. Monthly temperature (mean screen) and rainfall (Syfydrin, 1962–75).

TABLE 3. Tiller survival and spring production at Syfydrin after the 1961/62 winter

Species	Variety	Tiller No/m² Aug. 1961	Tiller No/m² May 1962	Production DM (Kg/ha) May 4 1962	Tiller No/m² May 1964
Agrostis tenuis	Br 616	3770	7880	200	7000
Alopecurus pratensis	S.55	1220	2840	510	3000
Anthoxanthum odoratum	Bs 2811	5340	7720	100	—
Cynosurus cristatus	N. Zealand	2630	3580	—	—
Dactylis glomerata	S.37	1840	400	—	—
	Medit.	3080	430	—	—
Festuca arundinacea	S.170	1750	2730	690	4100
	Medit. A	3060	1570	—	—
	Medit. B	3230	540	—	—
F. pratensis	S.215	2930	3170	260	6630
F. rubra	S.59	2420	6740	600	9000
Holcus lanatus	Commercial	6150	7220	—	—
Lolium multiflorum	S.22	3530	1440	110	—
	Westerwolds	1790	—	—	—
L. (*perenne* × *Multiflorum*)	N. Zealand	4010	2070	160	—
L. perenne	S.23	3350	6270	270	7130
	S.24	3800	3120	460	4570
	Melle	3920	5130	650	7930
	N. Zealand	3420	2960	280	—
Phleum bertolonii	S.50	4910	6310	830	5640
P. pratense	S.48	4400	5240	1010	4460
	S.51	4020	4140	1090	2150
	Scots	3260	3020	920	3300
Phalaris arundinacea	Bs 2778	1070	1960	380	1590
Poa pratensis	S.63	2340	6420	190	15650
P. trivalis	Denmark	3820	9520	300	—

in hill ewe nutrition (Russel and Eadie, 1968). The dominant indigenous species in the wetter hills, e.g., *Molinia*, do not commence growth until June and only continue for three months. Existing varieties of most grasses found on better hill areas, i.e., *Agrostis*, *Anthoxanthum*, *Cynosurus*, *Holcus* and *Poa pratensis*, were also markedly seasonal, producing less than 250 kg DM/ha in early May (Table 3). By contrast, S.59, a station bred red fescue (*Festuca rubra*) yielded 600 kg/ha, which was greater than the yield of the majority of perennial ryegrasses tested. S.48 and S.51 timothy exceeded 1 000 kg/ha.

Other Considerations

Leaf spot diseases (*Selenophoma* and *Drechslera* spp.) were prevalent on *Agrostis* and *Alopecurus*, and sheep showed low preference for *Anthoxanthum*, *Cynosurus*, *Glyceria* and some varieties of red fescue.

EXAMINATION OF YIELD CONSISTENCY UNDER CONTRASTING CONDITIONS

As a result of the preliminary screening, substantiated by previous experience in Wales (Davies, 1940) and Scotland (Hughes and Nicholson, 1962; Hunt, 1964), 21 species were eliminated, leaving only white clover, red fescue, timothy and perennial ryegrass for more detailed testing under extreme hill conditions. Other criteria were used in the assessment of material for grazing and conservation on drier land, and these will be reported separately.

Red Fescue-Timothy-Ryegrass Comparisons

From 1961–65, the performance of the three grasses of highest potential was studied at Syfydrin following three levels of lime application (2.5, 5.0 and 7.5 t/ha). Relative yields in 1965 are given in Table 4. S.59 red fescue gave the highest production at each lime level. This comparison was repeated at Pant-y-dŵr during 1966–69 on two contrasting soils, namely, freely drained brown earth and wet, anaerobic, N deficient stagnogley (Davies and Munro, 1974). S.48 timothy was used instead of S.50 and nitrogen treatments of 0, 134 and 269 kg N/ha per annum were substituted for the lime treatments. DM yield was highest from the red fescue in each year of the trial at all N levels (Fig. 2). A higher proportion of the yield of the fescue was produced in the spring and autumn (Table 5).

Further evidence of the wide tolerance of red fescue to adverse climatic and soil conditions, including moderate pH and N status, waterlogging and drought, has been obtained by the Hill Farming Research Organization in Scotland (Newbould, 1974).

TABLE 4. Comparative yields at 3 lime levels—Syfydrin 1965 (S.59 high lime = 4 000 kg/ha)

	Low Lime	Intermediate Lime	High Lime	Mean
S.59 red fescue	72	99	100	90
S.50 timothy	56	62	77	65
S.23 ryegrass	53	74	73	67

TABLE 5. Seasonal distribution of yield as a percentage of annual production—Pant-y-Dŵr 1967–69

	Brown earth			Stagnogley		
	Spring	Summer	Autumn	Spring	Summer	Autumn
S.59 red fescue	27	45	28	24	48	28
S.23 ryegrass	21	54	25	18	57	25
S.48 timothy	26	51	23	22	54	24

Comparison of Perennial Ryegrass Varieties

Evidence of the marked variation in yield possible from perennial ryegrass in different years and seasons in the hills is shown in Figure 3. Growth curves are for S.23 ryegrass on both brown earth and stagnogley soils from 1967–71 at Pant-y-dŵr. Total annual yields from swards receiving 269 kg N/ha varied from 4 000 to 6 900 kg DM/ha on the drier soil and 3 500 to 5 000 kg/ha on the peat, reflecting winter damage and summer moisture deficiency. The amount of winter damage was dependent on the level of N application.

Within perennial ryegrass, varieties differ widely in total and seasonal yield. Among 20 recommended and potential Station-bred varieties sown at Pant-y-dŵr in 1973, mean annual yields in 1974–75 ranged from 2 500–4 500 kg/ha. Compared with 1974, the reduction in the second harvest year because of drought ranged from 8–62% with an average of 29% (Munro *et al.*, 1976). Such fluctuation in yield is obviously of critical importance on heavily stocked hill farms.

FEED QUALITY EVALUATION

The real criterion of the value of any herbage plant lies in its capacity to supply the nutritional requirements of the animal. This is of particular importance in hill country where the natural vegetation is adapted to survival in an impoverished environment, the dominant species having a characteristically low energy, protein and mineral content (Munro *et al.*, 1973).

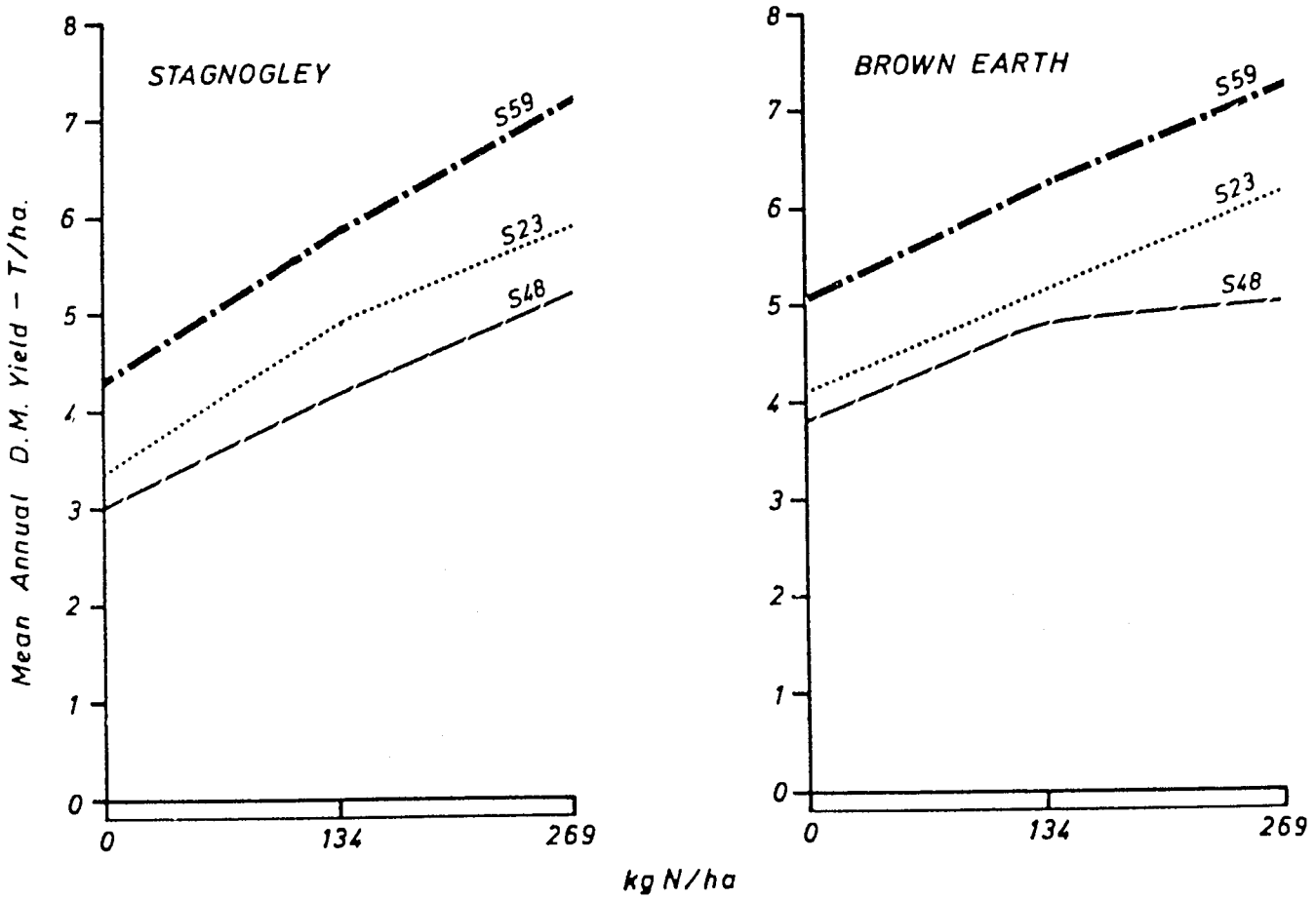

Figure 2. Herbage production from ryegrass, timothy and red fescue (Pant-y-dŵr, 1967–69).

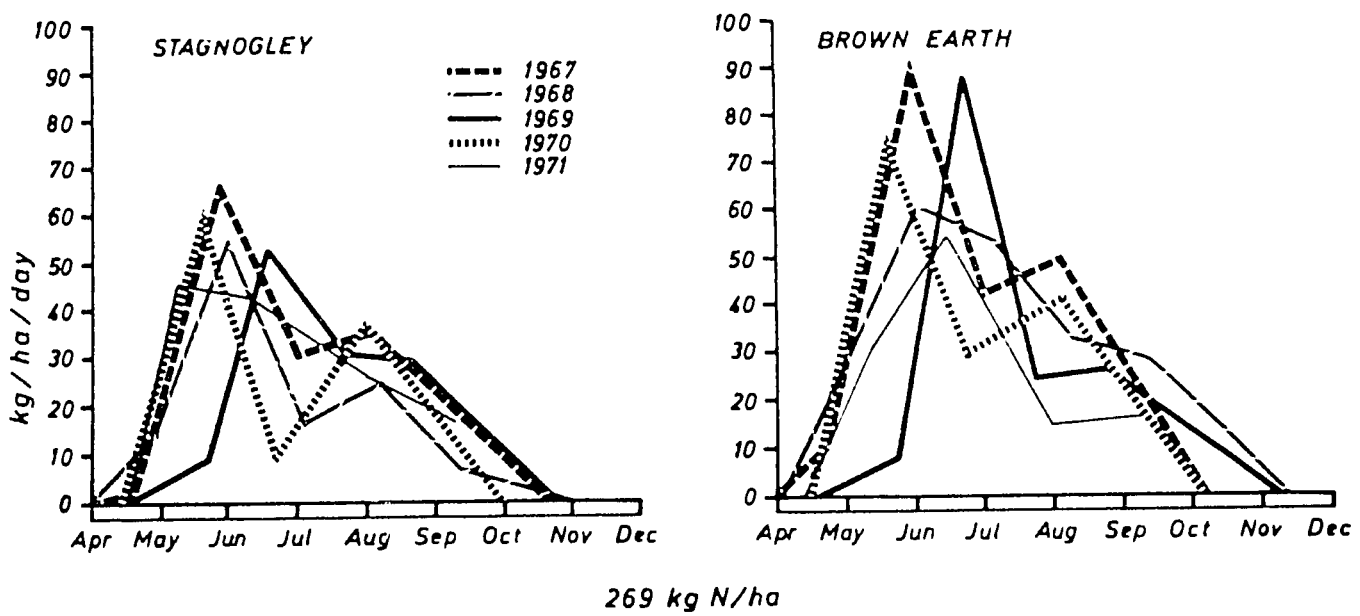

Figure 3. Growth rates of S.23 ryegrass (Pant-y-dŵr, 1967–71).

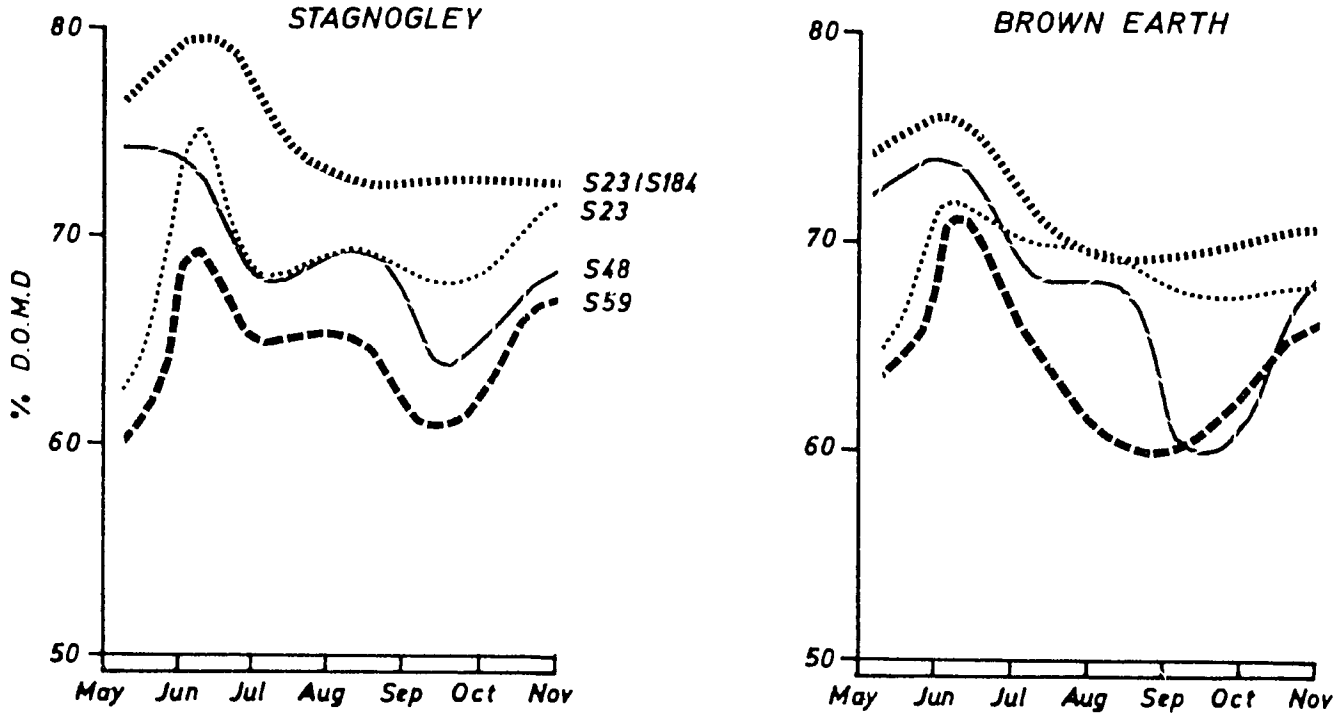

Figure 4. Seasonal pattern of digestibility (Pant-y-dŵr, 1967).

Digestibility is the most valuable single expression of nutritive value and laboratory *in vitro* determinations (Tilley and Terry, 1963) on new material are carried out early in the evaluation program. This method is now being replaced by a pepsin-cellulase method developed at the Station (Jones, 1975).

Preliminary assessments in 1967 highlighted possible nutritional short-comings in S.59 red fescue. The mean DOM of monthly cut herbage was only 64.5% in S.59 compared with 69% in S.23 ryegrass, 69% in S.48 timothy and 74% in mixed ryegrass/clover swards. The seasonal pattern is shown in Figure 4. However, despite the lower digestibility of the fescue the total annual DOM yield was 9% higher than S.23 on the brown earth and 14% higher on the stagnogley.

GRAZING TRIALS

Considerable resources are required for adequate study of animal performance, and grazing trials are only carried out in the final stages of evaluation. Intake is assessed under rotational grazing by pre- and post-grazing sampling of the herbage at weekly intervals. This is followed by analysis for digestibility, nitrogen, water-soluble carbohydrate (WSC) and mineral content. Ewe and lamb performance is measured by weekly weighing.

In a comparison of S.59 red fescue and S.23 ryegrass (Davies, 1975a; 1975b) poor gains in mid-summer from the fescue were associated with a rapid fall in digestibility due to early heading and stem formation. DOM intake was lower on the S.59 pastures, particularly in the period June 16–30 when it was only 88% of that on ryegrass. Over 130 days lamb liveweight was similar on the two species, but ewes on the fescues lost 50 g/day compared with a 15 g/day gain on ryegrass. Lower levels of WSC, sodium and cobalt were also recorded in S.59.

SPECIAL CONSIDERATIONS

White Clover Evaluation. For fifty years, white clover has been regarded as a key factor in hill land improvement in the United Kingdom but little information has been available regarding its precise contribution to the nitrogen economy and to pasture quality. From 1967–70 at Pant-y-dŵr, nitrogen fixation by the small-leaved S.184 variety was assessed at nearly 100 kg N/ha (Munro and Davies, 1974).

Several other white and alsike (*Trifolium hybridum*) clover varieties have been examined but none approach S.184 in persistence. A wider range of varieties is currently under examination with emphasis on establishment, spring growth and yield.

Varieties for Conservation. The improvement of the mountain pastures can result in a reduction in the spring grazing of the lower fields, leading to closing for silage up to four weeks earlier and the harvesting of two cuts instead of the more traditional single cut or hay crop. Less emphasis therefore is

placed on persistence and it is possible to use earlier-growing *Lolium multiflorum*, *L. multiflorum* × *L. perenne* and *L. multiflorum* × *Festuca pratensis* hybrids. In 1976, several varieties in these categories yielded over 10 000 kg DM/ha at Pant-y-dŵr in May and July harvests compared with 7 700 kg/ha from the best perennial ryegrass variety. New tetraploid *Trifolium pratense* varieties also show high promise.

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DISCUSSION

R. Blaser (Virginia, USA). It would seem to me that we have spent years and years working on varieties and on genotypes and we have often obtained fragmented research. I would like to know if you have given any thought to really putting some of these things into complete systems of management where farmers might be using them. It is so much easier to do the piecemeal work, but what are we going to do about putting these things in systems where we can use the information we have now.

Munro. Yesterday, it was mentioned that in the past there had been a lot in inadequacies in this way. I know nutritionists have not paid much attention to the agronomy side, whereas the agronomists are more concerned with improving the land without looking at responses in the animal. We are always thinking about the system; the results of this work in terms of the improvement of higher altitude pastures have been put into practice. You saw information presented on the scheme of the Ministry experimental husbandry farm which is carried out on land probably higher than any other land improved in the United Kingdom under very severe conditions, with over 3 000 mm of rainfall in difficult years. The mixtures used there were based on specifications drawn up from this work based on red fescue, timothy, ryegrass, and white clover. Similarly, we are trying to fit these new hybrids into the system so we are not looking at things in isolation. We do the testing, first of all, in small plots and in grazing trials on our station but as soon as possible we get on to the farm for the farmer's reaction, because, as you so rightly said, that is the final test of any variety.

J. Balasko, (West Virginia, USA). Tall fescue is a very desirable species in our area, as it is in many middle latitude states in the U.S. I am wondering whether or not you have looked at variability in the quality of tall fescue (*Festuca arundinacea*) and whether or not you feel that there will be much progress in the festuca-lolium crosses in terms of providing something that is as good agronomically as tall fescue is.

Munro. As I showed in one of the slides, we looked at tall fescue, but under the more extreme conditions it has serious limitations. In terms of early spring

production, it is very attractive because it is the earliest growing of the sown grasses on the hill, but its main shortcoming is slow establishment and very open swards thereafter. Another major shortcoming is the difficulty of management. As I said, these are mainly sheep systems and we have found that in order to manage tall fescue properly you have to have cattle in the system and you probably have to have a conservation cut as well in order to get away with the problems of stand formation and deterioration of quality. Because of these reasons we have stopped work on tall fescue at present but the hybrids with tall fescue and perennial ryegrass offer some potential.

25.
Hill Pasture Improvement in Galicia

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Galicia is the NW corner of Spain, situated just to the north of Portugal. It lies between 41°30′ and 43°30′ N latitude and represents a total area of 2.935 million ha (AEA, 1974). The topography is quite broken, with a predominance of undulating and hill land. Flat land is usually limited, except for the important plateau of central Galicia and a few other places. Flat land is also frequently isolated by considerable areas of hill country which delimit the numerous river valleys (García, 1975). Most of the country lies between 300 and 600 m. Limited mountainous areas are situated in the E and SE reaching altitudes of up to 1 400–1 800 m.

It is estimated that, in Galicia, hill country represents about 50% of the total area with 1.530 million ha (Azcára te, unpublished data). This area is constituted by coastal hill areas (200–400 m) and mountainous areas of over 1 000 m. Actually, about 60% of hill country is in an undeveloped stage, mainly dominated by scrub, together with reduced areas of rough pastures and woodland. Forestry plantations follow in percent of area occupied, and the remainder includes some permanent and improved pastures and occasional cropping. Therefore, the undeveloped hill country represents a tremendous land asset in a populated country such as Galicia, which has 0.386 million farms in its 2.935 million ha of total area (AEA, 1974).

CLIMATE

Galicia occupies a border area between the humid temperate coastal region of western Europe and the Mediterranean region. This is a climate with high annual rainfall but with a dry period during the summer; the poor distribution of rain is usually more unfavorable towards the S and SE. This factor, in addition to the normal variation from coastal to inland areas and from lower to higher altitudes, has resulted in the defining of five main climatic zones. We follow the classification of Walter and Lieth (1964):

1.V,IV.* Warm-temperate humid climate with a short dry period.
2.V,VI. Humid climate with short dry period and cold winter.
3.IV,V. Submediterranean coastal type.
4.IV,VI. Submediterranean with cold winter.
5.X. Mountainous areas over 1 000–1 200 m.

With respect to the hill country the importance of slope orientation must also be taken into account. In Galicia rains come, in general, with S-SW winds from autumn to spring and with N-NW winds in summer, therefore providing an advantage for north-oriented valleys and hillsides in summer.

SOILS

Soils are mainly derived from granites and schists, the remaining coming from sandstones, quartzites and some very localized basic rocks (Guitián *et al.*, 1969). As a result of low base content in the parent material (except for basic rocks) and winter leaching, soils are poor in bases and quite low in pH. Mean pH values for a large number of soil samples were pH (C1K) = 4.9 (pH (C1K): pH measured in C1K solution) for granite derived soils, 5.0 for schists and 5.4 for basic rocks, with the groups being significantly different (Munoz *et al.*, 1962).

*In this classification the main climatic components are given by Roman numbers, IV: mediterranean climate; V: warm-temperate humid climate; VI: humid climate with cold season; X: mountainous climate.

P contents were very low for all of the three groups, there being a considerable P-fixation for soils in the pH (C1K) range 4–6; this being about 50% greater than for soils of pH 6–6.5 (Munoz *et al.*, 1962). The situation was better in the case of K content, being mainly moderate to good, the granite-derived soils showing the lower values (Munoz *et al.*, 1962). Texture is light for granite and heavier for the other two groups (Guitian *et al.*, 1969). For similar topographic situations, soils over granite tend to be shallower. The organic matter content is high with a high C/N relationship, and poor humification.

Most of the hill country soils are classified as Ranker soils (unbrept) (A/C profile), which usually occupy hill tops and sides. When topography permits its development, humid brown earth (distrocrept) (A [B] C profile) is the climax soil and it is present in lower areas of hill country. A related soil is the subhumid brown earth present only in warmest and driest areas in the south. There are also small areas of localized podsolized soils (only over quartzites and sandstones) and organic soils. Variations of gley and pseudogley soils can appear due to local drainage conditions (CSIC, 1968).

VEGETATION

Undeveloped hill country is dominated by scrub, denominated generically by "heather" in this case. It appears mainly as a result of the deforestation of the community climax, forest dominated by oak trees (*Quercetea robori petreae*) and the degradation of conditions which might lead to its reversion. Only in altitudes over 1 200 m do poor mountainous pastures dominated by *Nardus stricta* appear and then only in isolated patches from 1 500 m onwards (Bellot *et al.*, 1962). There are four main types of scrub. (1) Scrub dominated by gorse with *Erica div. sp.* and *Calluna vulgaris: Ulicion nanae* community. Common gorse (*Ulex europaeus*) is present in coastal areas and wherever it was sown; dwarf gorse (*Ulex gallii* and *U. nanus*), on humid soils or inland areas. (2) *Ericion australis* community in the more continental and poorer situations where *Erica australis* and *E. arborea* and *Calluna* dominate the scrub. (3) *Cistion hirsuti* community in the submediterranean conditions. In addition to *Erica*, *Calluna* and gorse, *Cistaceae* species appear more abundantly. (4) *Sarothamnion scopariae* community dominated by broom (*Sarothamnus*, *Cytissus* and *Genista sp.*) (Bellot *et al.*, 1962).

The natural herbaceous vegetation which lives underneath and between the scrub (more or less abundant depending on the height and density of the scrub) is composed of rough grasses (like *Arrhenatherum thorei*, *Avena sulcata*, *Agrostis setacea*) with only traces of better grasses, some broadleave species (like *Hypochaeris radicata*, *Pedicularis silvatica*) and the bracken fern (*Pteris aquilina*). Almost the only legumes represented are *Lotus corniculatus* and *L. uliginosus* and these usually appear infrequently.

It is important to indicate some of the properties of the common gorse which make it difficult to control in an improving pasture. Gorse is a high seed producer, and large populations exist in soils under gorse. It has a high potential for growth and responds quite well to fertilizers. It recovers well after cutting, grazing or burning and finally, its hard thorns protect it from being eaten by most animals once it has outgrown the juvenile stage (during which it is soft and lacks thorns) (Sineiro, 1974).

TRADITIONAL USE OF HILL COUNTRY

In the traditional agriculture, hill areas were indirectly integrated into the existing farms. The most accessible areas were used for occasional cereal cropping (every 5–10 years) in a sort of long rotation scrub-cropping-scrub. During the scrub stage the area was cut several times to provide animal bedding and manure. After the last cutting sods were dug up, heaped and burned, and the ashes were spread over the whole paddock, usually as the only fertilizer for the following crop (mainly rye). Cropping followed for 1–2 years and then natural reversion to scrub took place again, giving some rough grazing in the initial stages. Since the last century, farmers used to mix gorse seeds (*Ulex europaeus*) with the last crop to promote a gorse-dominant scrub. Gorse was appreciated because of its high growth potential, its considerable N-fixation by rhizobia (Egunjobi, 1969) and the ready decomposition of the material cut from it to give a good manure (Carballas *et al.*, 1966). Other more unaccessible hill country was mainly dedicated to rough grazing and to providing some wood and timber. Most of the hill land was under communal use; even today 0.553 million ha are communal land (AEA, 1974). This kind of prevailing relationship of the hill country to the existing farms prevented in general the development of those areas in new farms. The decline of traditional agriculture opened the way to new uses for hill country: introduction of fertilizers as alternative sources to manure, use of stalls which do not require bedding and the fact that intermittent cropping was becoming uneconomical. Therefore, most of the hill country must be changed to directly productive land either for improved pastures or forestry plantations, leaving some for reserve land and leisure. Forestry plantations are much more advanced than pastures in their actual expansion on hill country. Work in hill pasture improvement began in the early 1960s (Nestlé, 1969; Zulueta, 1972). In the last ten years farmers have become aware of the potential of land development as pastures on hill country and this has increased in recent years.

PASTURE IMPROVEMENT

Pasture improvement includes the introduction of new species and improvement in soil fertility conditions followed by adequate management and by adequate and efficient systems of utilization by animals.

This study is mainly related to the first aspect of pasture improvement in hill land, i.e., pasture establishment, and it will consider some of the work done in systems of cultivation, responses to major nutrients at establishment and methods of sowing after cultivation, minimum tillage and no cultivation. Due to the large variation in conditions throughout the country it is necessary to lay down field trials in the main zones to evaluate the major variables in hill pasture improvement. In this first stage the five main climatic zones are followed and trials are being laid down on the most representative soils, one per zone.

LAND RECLAMATION WITH CULTIVATION

Early land reclamation used to follow a long process of cultivation using pioneer crops (1-3 years) or of fallowing the land for a year. These procedures had the advantages of leveling the land, improving soil preparation by means of repeated cultivations over long periods of time and depressing scrub weed populations (Nestlé, 1969; Zulueta, 1972). In an attempt to avoid long periods prior to pasture establishment, land reclamation direct from scrub to pasture in short periods was begun more recently.

Systems of Cultivation

In order to evaluate the effects of different systems of cultivation a trial was set up on an area of schist derived soil (depth 0.5-0.7 m) in zone 1. The elimination of scrub vegetation by cutting, or cutting and burning, was followed by three systems of cultivation: (1) heavy cultivator (light mixing of the soil); (2) rotovator (deep mixing of soil) and (3) plow (inversion of the soil). All these treatments were followed by a final preparation with a disc harrow and sowing with a mixture of perennial ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*) and white clover (*Trifolium repens*). Table 1 shows that early production of dry matter (DM) after cutting was significantly better after plowing than after the other two treatments. The disadvantage of plowing was that it brought stones up to the surface. The difference between cultivator and rotovator was not significant in spite of the poorer soil preparation at sowing for the former. After burning, differences in early production of DM were not significant, in part due to the high Standard Error (SE). Burning facilitated cultivation, especially in the case of cultivator and plow. Burning also led to an improvement in the DM production on the cultivator treatment.

TABLE 1. Production in MT DM/ha from sowing (9/75); 7/76— Zone 1 (Mabegondo—C)

Treatment	1. Cultivator	2. Rotovator	3. Plow
Cutting	1.75	1.63	2.25 SE = 0.17 LSD (5%) = 0.26
Burning	2.14	1.64	2.22 SE = 0.47 n.s.

(Sineiro, unpublished results.)

Fertilization at Establishment

In an attempt to measure the responses in pasture establishment to P, K, and lime several trials were laid down for the different zones. The same mixture was used for all the trials. It was composed of Italian ryegrass (*Lolium multiflorum*), cocksfoot, red clover (*Trifolium pratense*) and ladino white clover.

Table 2 lists the results of the first year's production for the P, K and lime trials on schist-derived soils in Zone 1 (Mabegondo). The results of P and K trials on granite-derived soils in Zone 2 (Parga) are shown in Table 3. The early DM production results for the P, K and lime trials in Zone 4 (Maceda) over quartzite-derived soils are presented in Table 4.

TABLE 2. Production in MT DM/ha during the first year (1974)— Zone 1 (Mabegondo—C), soil pH = 5.2

Phosphorus		Potassium		Lime	
Kg P_2O_5/ha	Prod.	Kg K_2O/ha	Prod.	MT Limestone/ha	Prod.
0	0.39	0	6.12	0	4.62
60	3.93	60	7.26	2.5	8.33
120	6.42	120	8.08	5.0	9.87
180	7.90	180	8.86	10.0	9.15
240	9.24	240	7.20	15.0	10.92
LSD (5%)	0.93		n.s.		2.37
CV (%)	12.1		23.0		20.3

(Piñeiro and Pérez, unpublished results.)

From the results of the three trials, a spectacular response to P up to high levels of 120-180 kg P_2O_5/ha (equivalent to 670-1 000 kg/ha of superphosphate) was evident. Response to K varied with soil type. There appeared to be a moderate response to the first level of K on the granite and schist-derived soils (40-60 kg K_2O/ha) and there appeared to be a good response on quartzite-derived soils in zone 4 (up to 120 kg K_2O/ha). From two trials (Tables 2 and 4) production was quite responsive to the first level of lime (2.5 MT ground limestone/ha of

TABLE 3. Production in MT DM/ha during the first year (1975)—
Zone 2 Parga-Lu.

Phosphorus		Potassium	
Kg P_2O_5/ha	Prod.	Kg K_2O/ha	Prod.
0	1.23	0	2.44
60	2.40	40	3.28
120	3.10	80	3.33
180	3.69	120	3.73
240	3.05	160	3.64
LSD (5%)	0.66		n.s.
S.E.	0.42		0.65

(Kiely and Gonzalez, unpublished results.)

TABLE 4. Production in MT DM/ha from sowing (9/75); 7/76—
Zone 4; Maceda-Or. soil pH = 4.9

Phosphorus		Potassium		Lime	
Kg P_2O_5/ha	Prod	Kg K_2O/ha	Prod.	MT Limestone/ha	Prod.
0	0.01	0	0.74	0	0.67
60	0.34	60	1.01	2.5	1.05
120	0.60	120	1.57	5.0	0.94
180	0.81	180	1.45	10.0	0.79
240	0.85				
LSD (5%)	0.28		0.42		0.28
S.E.	0.17		0.26		0.17

(Sineiro, unpublished results.)

44% CaO). Lime was indispensable for clover establishment: no clover was present where no limestone was applied, whereas it was adequately present from the first level onwards. Fertilizers appeared as the single most important factor (from the economic point of view) in pasture establishment, due mainly to the high responses to P and lime. This was quite a predictable result in view of the results of soil analysis by Muñoz *et al.* (1962) and the depletion of soil fertility which the traditional use of hill country imposed.

These high responses to fertilizers suggest the importance of studying the effect of fertilizer placement as a means of reducing the high rates needed and improving the efficiency of utilization, in view of the favorable results obtained in similar situations in New Zealand (Cullen, 1971). In this respect the good results obtained with the sodseeder in two trials can be explained in part by the effect of P and Ca placement (Tables 5 and 8).

Methods of Sowing

The effect of the method of sowing on pasture establishment on land coming from scrub in zone 1 was studied. After cutting and burning the scrub vegetation and cultivating the soil the following four treatments were compared: (1) rolling, conventional grassland roller seeder with a double Cambridge roller; (2) broadcasting plus compactation, the broadcasting of the seed followed by a firm compactation with the tractor wheels; (3) drilling, placement of P-Ca at normal rates; and (4) drilling, placement of P-Ca at half-normal rates.

Treatments 3 and 4 were rolled prior to sowing. P-Ca rates were 150 kg P_2O_5/ha and 3 MT of ground limestone/ha for treatments 1, 2 and 3, and half these rates for treatment 4. The mixture used was perennial ryegrass, cocksfoot and white clover. Early production results are shown in Table 5. Broadcasting plus compactation gave the highest DM production followed by drilling (normal P-Ca rates). Both

TABLE 5. Production in MT DM/ha from sowing (9/75); 7/76—
Zone 1 (Mabegondo—C)

Methods	1	2	3	4
Production	1.99	2.87	2.34	1.88
LSD (5%) =	0.38		SE = 0.24	

Sineiro, unpublished results
1. Conventional grassland roller seeder.
2. Broadcasting + heavy rolling.
3. Drilling. Localized normal P-Ca rates.
4. Drilling. Localized half P-Ca rates.

of them differed significantly from the other two treatments. Broadcasting appeared superior because of both uniform seed distribution and subsequent rapid covering of the ground by the sown plants and the firm compactation provided by the tractor wheels. The conventional grassland roller seeder did not appear adequate for pasture establishment on land coming straight from scrub. Rollers were light and did not cover the seed well or provide a firm seedbed. Clear lines of pasture bands coming from the drilling treatments testified to the good establishment. Clover establishment was better than for the other two treatments. Lower early production from drilling compared to broadcasting is normal, because plants have not yet covered the ground between sown lines. Results of drilling with half the rate of P-Ca were promising in terms of more efficient use of placed fertilizer.

Mixtures of Species

Two trials were set up to evaluate pasture production from four mixtures on land reclaimed by cultivation in zones 1 (Mabegondo) and 2 (Pargu-Lu). The mixtures were: (1) Italian ryegrass, cocksfoot, red and ladino white clover; (2) perennial ryegrass, cocksfoot and white clover; (3) perennial ryegrass and white clover, and (4) cocksfoot and white clover. The management regime was to cut whenever height of the pasture was 20–25 cm. Total DM production for the first year is shown in Table 6. Differences in production between the four mixtures were not significant in zone 1. Mixture 1 was superior to the others in zone 2; this result may have been due to a better exploitation of the environmental conditions through greater vigor of Italian ryegrass during the first year.

Comparing production obtained for established pastures in cropping land (Yepes *et al.*, 1972) with those of Table 6 for zone 1, the latter represents only about 50% of the former. Therefore, even taking into account the generally better conditions of cropping land, it is clear that there is a great potential for improvement by adequate management and soil fertility.

TABLE 6. Production in MT DM/ha, 1975

Mixtures	1	2	3	4		Mean of mixtures
Zone 1	5.82	5.49	5.67	5.44	SE=0.71 n.s.	5.61±0.10 (5%)
Zone 2	5.18	3.71	3.54	3.67	SE=0.44 LSD(5%)=0.70	4.03±0.13 (5%)

(Sineiro, unpublished results.)
Mixtures:
1. Italian ryegrass/cocksfoot/red and white clovers.
2. Perennial ryegrass/cocksfoot/white clover.
3. Perennial ryegrass/white clover.
4. Cocksfoot/white clover.

Minimum Tillage

Minimum tillage systems are important in reducing costs and in establishing pastures where more complete cultivation would be neither possible nor recommended because of erosion problems (excessive slope), abundance of surface stones or undrained wet soils.

In a demonstration set up in zone 4 (Maceda), three methods of land reclamation were compared. After cutting and burning the scrub vegetation, the following treatments were applied: (1) complete cultivation—plowing, disc harrowing and sowing; (2) minimum tillage—disc harrowing and sowing, and (3) no cultivation—oversowing. For each method two mixtures were used (1) Italian ryegrass, cocksfoot and white clover, and (2) Italian ryegrass, perennial ryegrass and white clover. The results of the first year production are shown in Table 7. Minimum tillage yielded interesting results in regard to the points mentioned above.

TABLE 7. Production in MT DM/ha 1975. Means of two mixtures—Zone 4. Maceda—Or.

Treatment	1	2	3
Total DM production	4.82 SE = 0.2	3.17 SE = 0.32	2.64 SE = 0.37
DM produced by sown species	4.09	2.54	1.06
% sown species	90	80	40

(Sineiro, unpublished results.)
Treatments:
1. Whole cultivation.
2. Minimum tillage.
3. No cultivation.

In order to further evaluate different systems of minimum tillage compared to no cultivation, a trial was set up in zone 1. There were four treatments after cutting or cutting and burning the scrub vegetation: (1) no cultivation, (2) disc harrow, (3) sodseeder—placement of P and Ca at normal rates and (4) sodseeder—placement of P and Ca at half normal rates. A mixture of perennial ryegrass, cocksfoot and white clover was used. The trial is being rotationally grazed by sheep.

Early DM production results after burning the scrub are shown in Table 8. Total DM yields were not significantly different. Statistically significant differences only appeared when the results were expressed as the yield provided by sown species. Sodseeding with normal rates of P and Ca was

TABLE 8. Production in MT DM/ha from sowing (9/75); 6/76—Zone 1 (Mabegondo—C)

Treatment	1	2	3	4	
Total DM production	1.71	1.83	2.18	1.77	n.s. SE = 0.33
DM produced by sown species	1.04	1.53	1.79	1.15	LSD (5%)=0.54 SE=0.26
% sown species	61	84	82	65	

(Sineiro, unpublished results.)
Treatments:
1. No cultivation.
2. Disc harrow.
3. Sodseeder. Normal P-Ca rates.
4. Sodseeder. Half P-Ca rates.

significantly greater than both no cultivation and sodseeding with half normal rates of P and Ca. Both sodseeding treatments gave better establishment of clover than the other two treatments. All treatments appeared better after cutting and burning than after cutting only. This can be explained by the removal of competition in early establishment and the better conditions provided for the action of machinery together with the small addition of nutrients provided by the ashes.

LAND DEVELOPMENT WITHOUT CULTIVATION

There is a considerable area of hill country in Galicia where the use of machinery is neither possible nor recommended. Therefore, the only way to improve pasture on such land is without cultivation. The follow-up of initial reclamation activities takes on a special importance in this case (this applies also mostly to the minimum tillage systems). The initial pastures are really much inferior to those usually achieved by cultivation. It will depend on management imposed whether the pasture either reverts to scrub again or improves with the years to become a highly productive pasture. Therefore, this kind of land development is understood in the context of the whole system of management (including animal management and systems of production) to carry the undeveloped scrub through to improved pastures.

A development system is being used which includes burning (with and without previous cutting of the scrub), oversowing and distribution of fertilizer. Grazing follows with short rotations and high concentrations of sheep (about 300/ha). The first grazing is given as soon as the pasture plants are able to resist being pulled out, plants being 7-10 cm in height.

Adequate burning has proved very important in eliminating early competition to oversown seeds and in depressing early regrowth from the scrub weeds. This last aspect can be seen in a trial in zone 1. The effects of a good compared to a light burning on the control of regrowth coming from gorse stumps are being measured. The same grazing management with sheep as described above was initiated after sowing.

Gorse stumps without regrowth or controlled regrowth were 98% in the case of the well-burnt area, and 58% in the light-burnt area, the difference being significant (Sineiro, unpublished). In both cases the imposed grazing management achieved an almost complete control of gorse seedlings. Experience to date suggests that burning should not be excessive so that the caking of surface can be avoided; if not, then it is harder to obtain a good establishment of plants, the ashes can be washed away and reduced water infiltration increases erosion problems.

Control of gorse, where necessary, can be done by herbicides; 2-4-5 -T has proved quite effective (Zulueta, 1972; Costa, INIA unpublished data).

Total first-year production ranged from 1.88 to 2.25 MT DM/ha (S.E. = 0.47) for five mixtures oversown after cutting and burning the initial scrub vegetation. Contribution of sown species was 20-35% (Sineiro, unpublished data). Trials in progress also attempt to evaluate reclamation by oversowing after only cutting the scrub. Early establishment appears to be more impaired by competition and regrowth of scrub is more severe. Early grazing seems more difficult and the animals need to be pushed harder.

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26.

Development and Productivity of Overseeded Pastures on Hill Country in Northern New South Wales, Australia

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The aerial seeding of pastures in Australia has been carried out sporadically for the last 25 years since the pioneering effort of A. S. Nivison in 1950 (McDonald, 1968). But its use has been confined mainly to the tableland areas of southeastern Australia, and results have generally been poor (Newman, 1966). In New South Wales, the potential for aerial seeding is immense, with four to five million ha of non-arable land in the state which can be improved only by aerial methods (Gruen and Pearse, 1959).

The northern tablelands (Fig. 1) of New South Wales (latitude 28°-32° S) cover an area of 2.8 million ha of which 1.3 million ha are classified as non-arable. It is estimated that over three quarters of this area carries natural pastures of low stock carrying capacity and is dominated by summer-growing native grasses. The rainfall pattern is summer dominant with 60% falling between October and March (Anon., 1964). The annual average precipitation ranges from 660 to 1 020 mm. Mean monthly temperatures vary from 5-9° C in July to 20-25° C in January (Spencer and Barrow, 1963). Snowfalls are light and infrequent and at least 50 frosts occur in winter (Anon., 1964). The soils are inherently fertile and respond readily to fertilizer application. Phosphorus, nitrogen and sulphur deficiencies are widespread (Spencer and Barrow, 1963).

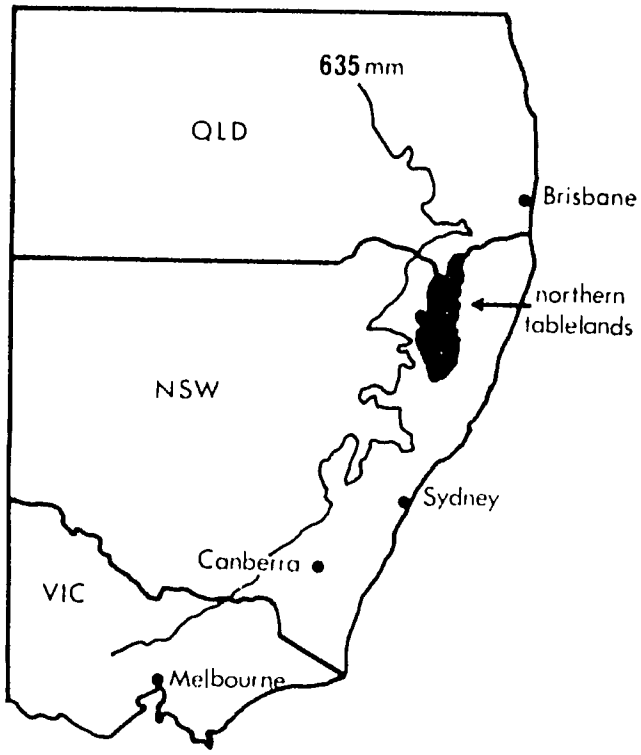

Figure 1. Location of northern tablelands, New South Wales, Australia. (After Anon., 1964)

The strategy for increasing livestock productivity revolves around the introduction of a legume into the sward. The main legume is white clover (*Trifolium repens*). It is relatively easy to introduce aerially, but the establishment and survival of persistent perennial grass species such as fescue (*Festuca arundinacea*), phalaris (*Phalaris aquatica*) and cocksfoot (*Dactylis glomerata*) have been less successful. Most research emphasis has therefore been on improving the level of establishment and survival of grasses overseeded on natural pastures.

The objective of this paper is to present some of the results of trials that I have conducted on the northern tablelands in recent years. In these trials, aerial treatments were simulated by applying seed, fertilizer and herbicide either by hand and hand-held equipment, or by ground machinery. All seed was sown onto an undisturbed soil surface.

OPTIMUM SEEDING TIME

In most countries optimum seeding time is fairly clearly defined, owing to restrictions of hot, dry summers and low temperatures over winter. Under the milder climate of the tablelands of New South Wales, seeding has been undertaken in all months of the year. Thus there was a need to determine the seeding time that would maximize the chance of success.

Establishment from 29 monthly sowings at Glen Innes was related to available soil moisture in the 6-week period following seeding ($r = 0.78$). This relationship between available soil moisture and establishment was then used to simulate establishment for 61 years, using historical rainfall data to estimate probability density functions of establishment throughout the year (Dowling and Smith, 1976).

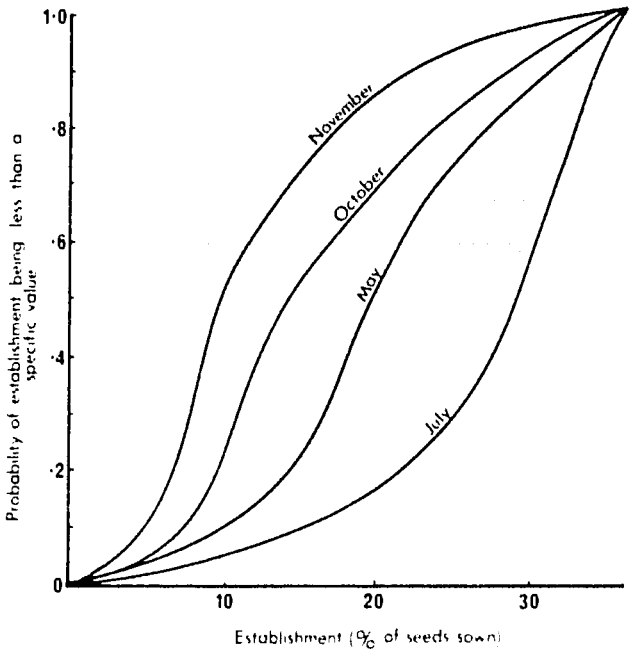

Figure 2. Cumulative probability distribution indicating extent of likely establishment success when seed is sown at several times throughout the year. (From Dowling and Smith, 1976.)

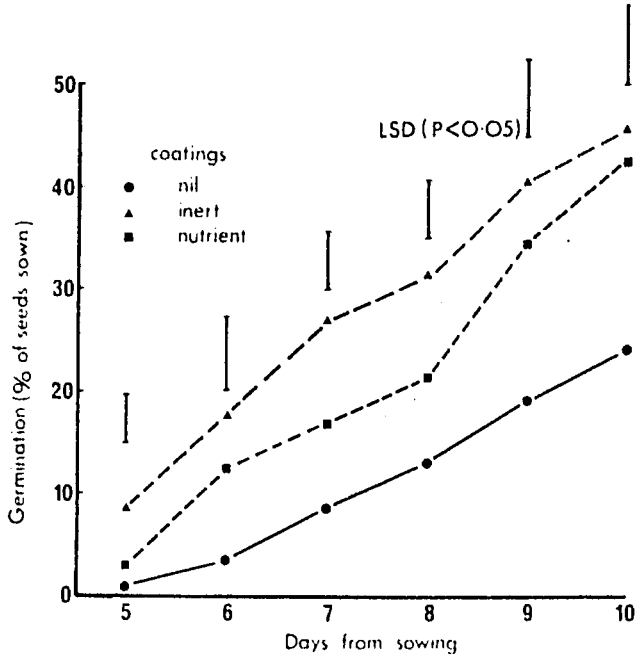

Figure 3. Effect of seed coatings on mean percentage germination of seeds placed on a bare soil surface in the glasshouse. Species sown were phalaris, perennial ryegrass, subterranean clover and lucerne.

From Fig. 2 it can be seen that the probability of maximum establishment occurring is greatest when an area is seeded during the June–July period and least when seeded during the warmer months of the year.

Data collected in this experiment show a close association between establishment, the growth stage at which a seedling becomes independent of seed reserves, and survival, which measures the ability of the seedling to survive its first summer. From the landowner's viewpoint, survival is of greater importance than establishment. With a June–July seeding, plants have more time to develop their root systems sufficiently to withstand moisture stress during the summer. Seeding earlier may mean reduced establishment (Fig. 2); seeding later, reduced survival.

SEED COATINGS

The use of seed coatings to improve establishment of oversown seed has been evaluated in the U.S. and New Zealand with widely divergent results (Hull *et al.*, 1963; Vartha and Clifford, 1973). The dramatic increases in establishment from coated seed in New Zealand prompted a similar line of work in Australia.

Two types of coating were compared with uncoated seed from the same seed source. Species used were phalaris, ryegrass, subterranean clover and lucerne. Both coatings significantly increased germination on a bare soil surface in the glasshouse (Fig. 3). In the field, establishment from coated seed significantly exceeded that of uncoated seed in only 20% of seedings, these being during the warmer months of the year when aerial seeding would not normally be considered. Coating generally depressed germination in petri dishes.

The contrast between my results and those obtained in New Zealand (Vartha and Clifford, 1973; Scott, 1975) was probably caused by a greater amount of vegetative cover (ca. 5 000 kg/ha) compared with the sparse ground cover in the New Zealand work. The higher relative humidity at ground level under vegetative cover probably achieves the same net effect as the seed coating. Presence of cover may nullify the effect of the seed coating.

VEGETATIVE COVER

Establishment from overseedings in drier and more variable rainfall environments has been shown to improve when ground cover is present (Pratt, 1964; Dowling *et al.*, 1971). Several reasons for this response to cover have been suggested and include increased soil moisture content (Glendening, 1942); reduced temperature variation (Evans and Young, 1970); reduced soil strength and increased heterogeneity of soil surface allowing easier entry for radicles (Campbell and Swain, 1973); and increased relative humidity (Young and Evans, 1972).

Results from a field experiment on the northern tablelands showed that temperatures were more

favorable and relative humidity was increased under cover. The mean effects of cover on relative humidity, temperature and establishment are shown in Table 1.

Since temperature is not a major limitation in our environment, the increase in establishment under heavy cover is attributed to relative humidity.

TABLE 1. Effect of vegetative cover on relative humidity, temperature and mean establishment measured two months after seeding in late autumn

	Light cover	Heavy cover	L.S.D. ($P < 0.05$)
Relative humidity (%)	60	90	3
Temperature (C)	20.1	12.6	1.4
Establishment (%)	1.0	9.2	4.0

HERBICIDES

Results presented above have been concerned with improvement of establishment. Establishment can also be improved by herbicide application before sowing, but its main effect in southeastern Australia is to ensure survival by reducing competition for moisture and light from the resident sward. On the southern tablelands, herbicide use is obligatory for survival (Dowling *et al.*, 1971).

On the northern tablelands survival of perennial grass species was improved by the application of herbicide, but its use was not essential for survival. Table 2 shows that herbicide markedly improved survival whenever the interval between seeding and sampling was six months or more.

Alternative methods for competition control, such as burning or grazing before seeding, offer little scope under tableland conditions, since both methods remove the protective litter.

TABLE 2. Mean effect of herbicide on number of sown plants/m^2 at various intervals after seeding. Species sown were phalaris, fescue, cocksfoot, subterranean clover and lucerne (experiment 1); phalaris, fescue, cocksfoot and perennial ryegrass (experiment 2)

	Experiment 1			Experiment 2		
Time interval between sowing and sampling (months)	2	6	11	6	12	24
Herbicide	13.8	20.3	11.8	54.0	18.3	11.0
Control	11.1	9.5	5.2	29.3	1.7	3.7
L.S.D. ($P < 0.05$)	9.9	4.1	3.0	12.6	4.7	6.6

Strategic grazing after seeding at heavy stocking rates (e.g., 400 sheep/ha) for short durations during periods when the sown species are under stress from the resident sward is a cheap alternative. Unfortunately this technique has not been fully evaluated in the field.

Herbicide application is our most successful method of controlling competition and ensuring more rapid development of the sown plants, but it is expensive. Therefore, cheaper alternatives are required.

Two lines of investigation which sought to do this were undertaken. The first aimed to substitute heavier seeding rates for herbicide (Table 3). Substitution of herbicide by heavier seeding rates of fescue appears possible, since there were as many plants on the heaviest seeding rate without herbicide as there were at the lightest seeding rate with herbicide. When cheap seed is available, therefore, heavier seeding rates of fescue may be practicable. With species having poor seedling vigor such as phalaris, however, there is little point in attempting such substitution.

TABLE 3. Effect of herbicide (2,2-DPA plus amitrole) and sowing rate on plants/m^2 of fescue and phalaris ten months after sowing (data from Dowling and Robinson [1976])

	Sowing rate (kg/ha)	Herbicide rate Control	Light	Heavy
Fescue	2	0.5^{a}	3.0^{ab}	10.5^{c}
	4	5.0^{b}	12.0^{cd}	15.5^{d}
	7	3.0^{ab}	29.0^{e}	27.0^{e}
	15	10.5^{c}	26.0^{e}	66.0^{f}
Phalaris	4	0^{a}	1.5^{ab}	13.0^{d}
	7	0^{a}	4.0^{bc}	13.0^{d}
	15	0^{a}	10.0^{d}	25.5^{e}
	31	1.0^{ab}	5.0^{c}	32.5^{f}

Means within each species followed by the same letter(s) are not significantly different—L.S.D. ($P < 0.05$).

The second investigation aimed at reducing the cost of competition control by lowering herbicide rates. It was found over a number of spraying times throughout the year and with a variety of herbicide mixtures (e.g., 2,2-DPA; 2,2-DPA plus amitrole; 2,2-DPA plus 2,4-D), that as the degree of competition control declined, so did survival (Table 3).

EVALUATION OF PASTURE DEVELOPMENT METHODS

The cheapest method of raising productivity of non-arable land on the northern tablelands is with white clover and superphosphate. Further increases in productivity and some degree of bloat control

(by reducing white clover dominance) can be achieved with winter green perennial grasses, provided they can be satisfactorily introduced. However, no comparative data were available on the productivity and profitability of various methods of pasture development.

Consequently a field trial on the improved natural pasture consisting of white clover and summer-growing native grasses was commenced at Glen Innes in 1972. The trial aimed to compare three different levels of aerial pasture development on productivity and profitability using three sheep stocking rates (5.0, 7.4 and 9.9 wethers/ha). The three levels of pasture development were (1) superphosphate alone—the most widely practiced form of aerial development; (2) superphosphate plus perennial grass seed—normal farm practice where seed is sown; and (3) superphosphate plus perennial grass seed plus prior application of herbicide—the best available method for introducing perennial grass on non-arable land.

In each of the three years of the trial, sheep grazing treatment (3) were consistently heavier, and produced more wool per head, than sheep grazing the other treatments. The liveweight advantage at most sampling periods (every six weeks) was 2–3 kg/head. Liveweight and wool production trends were similar on treatments 1 and 2.

Over the three years, wool production per head generally declined as stocking rate increased, though the pattern and rate of decline differed with method of pasture development (Table 4). This decline was small on the herbicide treatment.

Wool production/ha was improved as both stocking rate and level of pasture development were increased (Table 4). The effect of herbicide was most noticeable at the heaviest stocking rate. Most of the animal response to treatment 3 was attributed to the greater availability of better quality forage in the form of the sown grasses, since herbicide depressed overall pasture availability particularly during the initial phase of the trial (Table 5).

TABLE 4. Mean wool production (kg) per head and per hectare, as affected by stocking rate and treatment

Treatment	Stocking rate 5.0		7.4		9.9		L.S.D. ($P < 0.05$) between means	
	hd	ha	hd	ha	hd	ha	hd	ha
(1) Superphosphate	6.7	33.2	6.3	46.7	5.9	58.0		
(2) Superphosphate plus grass seed	6.3	31.0	6.7	49.3	5.8	57.1	1.0	8.6
(3) Superphosphate plus grass seed plus herbicide	6.9	34.3	7.0	52.0	6.7	65.9		

TABLE 5. Availability of sown grass (as a % of available dry matter) and total amount of pasture available (kg dry matter/ha) during the winters of 1973, 1974, and 1975

Treatment	1973 Sown	1973 Total	1974 Sown	1974 Total	1975 Sown	1975 Total
	%	kg/ha	%	kg/ha	%	kg/ha
(1) Superphosphate	0	3610	0	3430	0	3600
(2) Superphosphate plus grass seed	0.1	3540	2.9	3380	9.6	3510
(3) Superphosphate plus grass seed plus herbicide	1.5	2760	13.1	2700	19.3	3270
L.S.D. ($P < 0.05$) between treatment means	5.1	n.s.	1.0	n.s.	6.1	n.s.

Percentage availability of sown grasses improved with time (treatments 2 and 3). This was attributable both to seedling regeneration and development of the original sown plants and was achieved under a continuously stocked system. This result suggests that in our environment the contribution by sown grasses to overall productivity increases with time, and that the rate of improvement is increased by the herbicide treatment.

Assessment of profitability of the three treatments at this stage is incomplete. However, the results suggest that percentage return to capital invested increases with stocking rate, but declines as the cost of the treatment increases. Thus it may be more profitable to apply superphosphate only and increase the stocking rate.

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DISCUSSION

J. Winch (Ontario, Canada). You said that with your pelleted seed you had an increase in establishment on small areas but when you took it out to the field you could not see any advantage. Is that correct?

Dowling. We had an increase in germination on a bare soil surface and when we took it out into field conditions we were not looking at germination but at establishment, which is the stage beyond. We had limited success with the coating treatments. We had situations where the coated seed was superior to that from uncoated seed but only in 20% of the seedlings. In the other 80%, the uncoated controls were superior to the coated.

27.

Aerial Application of Herbicides, Seed and Fertilizer Improves Forage on Ozark Hill Lands*

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Our experience with hill land improvement in the Ozark Highland area in midwestern United States involves brush control, seeding and fertilizing by aircraft.

The Ozark Highland is a plateau and mountain area of more than 11 million ha in southern Missouri, northern Arkansas (including the Boston Mountain Range) and northeastern Oklahoma. Its soils, which have been leached for millions of years, are deficient in P and K. On many areas of level topography, soils have developed compacted layers limiting root penetration at varying depths. The soils derived from limestone or dolomitic limestone may contain as much as 75% residual chert fragments. The soils generally have poor water-holding capacity (Krusekopf, 1963).

*Approved by the director as a contribution from the Missouri Agricultural Experiment Station (Journal Series No. 7611.)

CLIMATE

The southern and southeastern Ozarks have a climate similar to that of the humid forest regions. Precipitation averages 130 to 140 cm, distributed throughout the year. Winters are usually mild; the growing season may be as long as 215 days, depending on elevation. By contrast, the northern and northwestern Ozarks have a more continental subhumid climate with about 100 cm of annual rainfall. The temperature fluctuations are greater, and the growing season varies from 170 to 180 days. Summer droughts are common.

VEGETATION

The Ozarks form a transition zone between the oak-hickory woodlands of the East and South and the tall grass prairies of the West and North. White oak (*Quercus alba*), black oak (*Q. velutina*) and several species of hickory (*Carya* spp.) are common on the deeper soils in the forest regions. Post oak

(*Q. stellata*) and blackjack oak (*Q. marilandica*) are prevalent on the more shallow droughty soils and become common farther west (Krusekopf, 1963). Native grasses, including little bluestem (*Andropogon scoparius*), big bluestem (*A. gerardii*), broomsedge (*A. virginicus*), indiangrass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*) are common in open areas throughout the Ozarks and abundant in the native prairies bordering the Ozarks.

EARLIER CROPPING PRACTICES

When settlers came to the Ozarks, the vegetation was of the savanah type (Dykersterhius, 1957). Marbut (1911) reported that up to the middle of the nineteenth century, the Ozarks were a region of open woods with large areas being almost treeless, and the timber was not dense enough to hinder the growth of grass. Dense timber was present on the rougher land and along drainageways. Accidental or intentional burning of the dense grass kept the woody species from becoming dominant in the grassland; however, as the settlers increased, grazing was so intense that the accumulation of grass fuel decreased and fires were no longer intense enough to control sprouts. Thus, formerly productive grasslands were taken over by vigorous, dense stands of wood vegetation, and growth of forage was substantially reduced (Dykersterhius, 1957). Mowing, chopping and girdling were commonly practiced to control brush before herbicides and bulldozing became available, but these methods required too great an effort for the economic return.

Along with chopping, mowing and girdling, fire was also used as a tool; because of insufficient fuel, however, fires usually were not hot enough to control brush. Fires many times were not controlled, and they did considerable damage to valuable timber and other property; therefore, fire was discouraged as a tool for brush control. More recently, however, fire has been reevaluated as a tool and has been used under prescribed conditions (Ehrenreich and Crosby, 1960b).

Bulldozing is used to remove brush on large tracts. It is not entirely satisfactory because it disturbs the soil and leaves it open to erosion that can be disastrous on steep slopes. Trees are usually uprooted and pushed into the drainageways along with large amounts of soil that cling to the tree roots. Organic matter at the surface is often removed. Bulldozing frequently leaves enough underground portions of trees so that regrowth of woody vegetation becomes a problem. Bulldozing also is expensive—costs can vary depending on the density of the stand and may exceed $250/ha on dense stands. However, a thorough job of bulldozing leaves the soil in such condition that a seedbed can be easily prepared for seeding forage species.

Before the mid-1950's, even when the farmer was successful in controlling brush adequately, forage was difficult to obtain because he depended largely on natural reseeding of native grasses. This was a slow process, because most of the native grasses were eliminated by abusive grazing, and the remaining plants did not produce adequate seed to rapidly revegetate the area (Davis, 1967). Supplies of native grass seeds were not locally available for sowing. The sowing of introduced cool-season grasses met with limited success, because the available species did not survive the droughty and infertile soil conditions. Rough terrain made application of fertilizers difficult; seedbed preparation in many cases was impossible.

PRESENT PRACTICES

After World War II, several developments led to renewed interest in control of brush and production of grass: (1) the introduction of herbicides provided a relatively economical and easy way to suppress brush; (2) ways of producing more economical supplies of native grass seed were developed; (3) it was discovered that Kentucky 31 tall fescue (*Festuca arundinacea*) would survive droughty conditions; (4) it was realized that fertilizers would increase grass production on the infertile soils of the Ozarks; and (5) aircraft were adapted to spray, seed and fertilize rough terrain.

Brush Control by Aerial Spraying

During the early 1960's, research was done on aerial applications of phenoxy compounds for controlling brush. This work showed that 2, 4, 5-T ([2, 4, 5-trichlorophenoxy] acetic acid), silvex (2-[2, 4, 5-trichlorophenoxy] propionic acid), dichloroprop (2-[2, 4-dichlorophenoxy] propionic acid), and 2, 4-D ([2, 4-dichlorophenoxy] acetic acid) or mixtures of these could be applied in low volumes of solution (20 to 50 l/ha) for controlling brush. Ester formulations of these compounds usually were more effective than amine formulations. These compounds generally removed 50 to 90% of the woody foliage and killed 30 to 70% or more of the woody species (Crawford, 1960; Elwell, 1964; Peters *et al.*, 1960; and Vogel and Peters, 1961). Removal of at least 70% of the canopy was necessary for grasses to thrive (Ehrenreich and Crosby 1960a). A second and sometimes a third application was generally necessary to achieve about 90% control of woody species. Complete death of all woody species was seldom attained, and maintenance treatments were needed later.

Spraying is usually most successful after the tree leaves attain full size in spring and early summer. Herbicides appear to be less effective as the season progresses.

The use of aircraft to apply herbicides has made it possible to spray large areas; in Missouri alone, more than 24 000 ha of brush were sprayed annually from 1968 to 1974.

The present practice of killing brush with phenoxy herbicides in order to seed and improve pastures is not entirely satisfactory, but farmers accept it because it is economical and relatively successful. Ideally, a herbicide should kill nearly 100% of the brush with a single application. The phenoxy herbicides kill only 30 to 60% of the susceptible oaks and hickorys with one application and are almost ineffective on resistant species such as winged elm (*Ulmus alata*), sassafras (*Sassafras albidum*) and persimmon (*Diospyros virginiana*). However, they are economical enough to increase forage production. Furthermore, the phenoxy herbicides are relatively safe when used properly. Other herbicides have been developed that are more effective than the phenoxy herbicides, but they have not been used because of cost, residual characteristics, lack of selectivity, and possible hazards. Also, some of the herbicides available have not been fully evaluated for use.

A major objection to aerial spraying is that the dead trees provide an unpleasant site for several years after spraying. Sometimes these trees are pushed over, piled and burned. After a few years, trees killed by spraying break off or are uprooted easily, leaving the soil in place. Some farmers permit the dead trees to stand until they decompose and fall.

Seedbed Preparation

In 1956, personnel of the Agricultural Research Service and Forest Service, USDA, showed that tall fescue could become established in leaf litter, but that better establishment was obtained when the upper portion of the litter was removed either by raking or burning (Ehrenreich and Buttery, 1960; Peters and Ehrenreich, 1964; Vogel and Peters, 1961).

When tall fescue, orchardgrass or native grasses are to be sown, the sites are prepared in late August or early September by burning the leaf litter. Deep leaf litter prevents the roots of newly germinated grass from reaching the moist humus on the soil surface. Burning usually consumes the less decomposed organic matter on the surface and the moist organic matter underneath remains. Grass is then sown into the ashes and becomes covered by the first rain. If native grasses are sown, they are usually sown in February or March because they start slowly and need a long growing season to become established. Burning to establish a seedbed in February and March before seeding native grasses is difficult because the litter is seldom dry enough to burn satisfactorily (Ehrenreich and Buttery, 1960). The benefit from burning before seeding is reflected by forage yields taken four years after seeding (Table 1).

TABLE 1. Yields of forage grasses on burned and unburned areas four years after seeding

Grasses	Burned	Unburned
	kg/ha	kg/ha
Native grasses	3 048	1 455
Tall Fescue	2 263	1 240

Liming and Fertilizer

Almost all of the soils are acid and benefit from applications of lime. The large bulk involved in application of lime makes it impractical to apply lime by air. When the terrain is not too steep, farmers may push over dead trees and form lanes 12 to 15 m apart to permit the passage of lime spreaders, which are equipped with fans that throw the lime to the back and to the sides to cover a 12 to 15 m swath.

Since the areas are low in P and K, these are applied either aerially or by ground operations. When applied by air, fertilizers containing high concentrations of nutrients are used to reduce application costs.

Species Selection

Cattlemen are interested in the possibilities of using native warm-season grasses to supply forage during the summer when tall fescue does poorly (Rountree *et al.*, 1974).

Few native warm-season grasses have been sown aerially. Research and farmer experience show that native grasses can be established in burned litter. These grasses may have a major place on hot droughty west and south slopes where they produce better than fescue. The native grasses also do well on the east and north slopes and on deep soil. Careful management is necessary to maintain stands of native grasses.

Management

Once forage is established, careful management practices are needed to maintain it. After the brush is killed, and if the pastures deteriorate, it may be difficult to reestablish grasses. Leaf litter will no longer be present to supply cover and moisture for grass seed to germinate and grow. Seeding them may be a problem unless a seedbed can be prepared. Nutrients from decomposing litter furnish nitrogen and minerals to the grasses for a few years after establishment; later, yields decrease and nutrient deficiencies become apparent.

On the rougher terrain where ground application is impractical, supplying N for maximum growth may not be economical. P and K can be applied aerially and will remain available for several years,

but N should be applied annually, but the cost of fertilizer and application may be prohibitive.

Supplying N through legumes is a possibility. Sowing and maintaining legumes in sprayed areas needs to be more fully evaluated. Where periodic spraying of brush is needed for control of sprouts, the legumes will be severely injured and usually eliminated. Because of the droughty conditions of the soil and environmental conditions, the choice of legume species is limited. Annual lespedeza (*Lespedeza striata*) has some characteristics that may make it useful, but production is limited by dry conditions. This lespedeza usually has a high percentage of hard seeds and, after it is grown for several years, the supply of hard seeds in the soil may be adequate to regenerate new stands in subsequent years after a stand is eliminated by herbicides applied to brush. Annual hop clovers (*Trifolium agrarium*) furnish some N on the more moist soils. These species may regenerate after spraying as does annual lespedeza. Perennial sericea lespedeza (*Lespedeza cuneata*) grows well and tolerates drought; however, its palatability is low. Even so, it may be valuable to supply N. A number of native legumes (*Lespedeza*, *Cassia* and *Desmodium* spp) are present, but these seldom are dense enough to produce much forage.

Economics

Both helicopters and fixed-wing aircraft are used for spraying, seeding and fertilizing. Helicopters have the advantage of being able to land and load near the site of operation, thus saving considerable time compared with fixed-wing planes which frequently have to travel farther. Time is an important factor when spraying because spraying can be done only for an hour or two in the early morning or evening on days when the wind is at a minimum. If spraying is done when the wind is blowing, spray may drift off the target area and cause damage to other areas.

The large amount of spraying practiced in the Ozarks has revived the unresolved question of what is the best use of the land. How much of the area should be sprayed to grow grass and how much should be managed for timber? Many of these sites have poor stands of timber and because of soil conditions, have poor potential for timber. Other sites have poor timber stands but good potential for timber production. The best soils produce good yields of either timber or grass. Ehrenreich and Ralston (1963) studied the economics of timber and grass production on shallow soils and concluded that grass production was more profitable than timber production. At the present time, the private landowner decides whether he wants grass or timber; economics plays a large part in his decision.

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DISCUSSION

Unidentified. This fascinates me. I think we could use it in Appalachia. Did you say that the pH in the soils in Missouri was relatively low? Did you apply lime? Also, have you considered ladino clover or have you tried any other legume on these areas?

Peters. Yes, we have considered ladino clover and it is used somewhat in some of the creek bottoms, but the soil is generally too droughty and ladino won't survive. Now your question about lime—this was another problem. We cannot apply it by air because the cost is prohibitive. Generally the cost for aerial application of fertilizer runs about 1½ cents/lb, but we can use high analysis material, so this is not prohibitive. However, if you are applying several tons of lime at 1½ cents/lb, this is another problem. Some of the farmers will push the dead trees out of the way in swaths about every 50 feet and use lime spreaders. This has worked well.

Unidentified. Have you tried crownvetch in these areas?

Peters. Yes, a few farmers are growing crownvetch, but we are not sure if we can establish it. Some of our innovators are doing it but it does not persist. The more successful stands seem to be on thin soils on the glades where the limestone is not very far away from the surface and I think at these pHs, the vetch roots get next to the calcium layer and they seem to do well. Dr. Matches has been working with crownvetch in Missouri and it seems to have some limitations.

Unidentified. How do you control burning?

Peters. Use boundaries, for instance, roads. Frequently, we will rake a fire line, rake the leaves away from an area 3 to 5 m wide and get down to the more decayed organic matter. Do this when the wind is not blowing, or if you have a little wind, make sure it is in the proper direction and have some equipment around to wet down the areas. The farmers say it is not much of a problem. They say frequently the fire will burn into an adjacent forest area but it goes out immediately as soon as it hits the litter in there. The litter seems to be moist at this time of the year. If we have exceptionally dry weather, we do not burn at all.

28.
Production and Species Composition of Hill Pastures as Influenced By Lime and Fertilizer

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In West Virginia there are more than 740 000 hectares of permanent pasture. Nearly two-thirds of this area is in land classes V through VIII (USDA, 1970). Due to natural limitations these soils can not be used for any sound agricultural purpose other than pasture. Much of this pasture land is located in regions with favorable climatic conditions and it has been shown in several investigations that production can be increased by various treatments (Odland *et al.*, 1930; Robinson and Pierre, 1938; Pohlman and Cornell, 1943; Schaller and Pohlman, 1955). Although treatment is possible, a survey in 1935 (Pierre *et al.*, 1937) revealed that 85% of the pastures in the state needed lime and 94% needed phosphate. More recently the West Virginia Soil and Water Conservation Needs Inventory (USDA, 1970) revealed that only about 6% of the state's total pasture land was adequately treated. From such data it seems obvious that progress in improving permanent pastures has been slow or nonexistent. One of the reasons sometimes given to account for the lack of treatment is that the response to treatment is not adequate to justify the cost. However, the response in terms of yield, species composition, and distribution of production to present treatment recommendations is not well documented. This investigation was undertaken to determine the response of various permanent pastures to treatment according to present West Virginia University recommendations.

PROCEDURE

In 1971, 13 different permanent pasture sites in central West Virginia were chosen to study the influence of fertilizer and lime applied according to University recommendations for bluegrass-white clover (*Poa pratensis* L.-*Trifolium repens* L.) permanent pastures. Total yield, season of production, and sward legume content were examined. Soil samples were taken from each site and treatments were applied in early spring, 1971. The treatments consisted of applying sufficient lime to raise the pH to a minimum of 6.5 and applying potassium and phosphate according to bluegrass-white clover permanent pasture recommendations for intensive management. This amounted to supplying sufficient K for the soil to test a minimum of 179 kg available K_2O/ha. Sufficient phosphate was applied to provide 56 kg P_2O_5/ha initially plus an additional 56 kg/ha for each year of the study. Phosphate treatment recommendations are commonly made for an alternate-year application, however, phosphate was applied in sufficient quantity to provide a five-year supply. Work at West Virginia (Schaller and Pohlman, 1955) revealed little difference in yield associated with frequency of application, but a direct relation between yield and rate of application. After the first year, no additional lime or phosphate was added but K was added during the study to maintain

the soil level at a minimum value of 179 kg available K_2O/ha. The addition of K during the study was necessary to replace the K removed in the forage. On the soils studied, K fertilization could be minimal or none since natural weathering of the soil and the return of plant and animal residues would maintain a soil K lev of 179 kg/ha when used as pasture.

Two or more areas were treated at each site and protected from grazing animals by 1.2 × 1.2 m pasture cages. The forage produced was harvested when it reached a height of 10 to 20 cm. At the time of harvest, the percent legume content on a weight basis was estimated and dry matter yield was calculated after drying the forage in a forced air oven at 70° C.

The number of days between harvests was used to determine the average amount of forage produced each day. Forage yield distribution patterns were calculated from the amount of forage produced daily.

RESULTS AND DISCUSSION

Table 1 gives a description of the soil and topography at each site. The lime applied raised the pH of the top 5 cm of soil to 6.5 in all cases. The soil at site 8 was not limed because it could not be done with conventional farm equipment due to the slope. The site is typical of considerable acreage in central West Virginia that is frequently fertilized without liming, yet the response is reported by landowners to be good.

Yields

Table 2 gives the yield for each site on a year-by-year basis for both the check and treated plots. Although treatment did not always increase yields, when all sites were combined, the treated areas produced higher yields than the check areas in each of the five years. The average yield of treated plots was higher than the check by 19% in 1971, 26% in 1972, 17% in 1973, 11% in 1974 and 4% in 1975. It would seem that to maintain productivity another application should have been made at the end of three years before low phosphate values apparently limited production.

Sites 4, 9, and 13 show little or no response due to treatment. Site 4 was very fertile and had productive species in the sward prior to treatment. This probably accounted for the check yield being as high as the treatment yield. Site 9 was the second most productive site when untreated and like site 4 had a high level of fertility and productive species before the study began. Site 13 was not very responsive to treatment although the treated area out-yielded the check four of the five years. At the ten other sites the treated area produced more forage than the check area.

The highest yield recorded was from site 4 each of the five years. Yet Table 1 reveals that site 6 was similar in exposure, slope, and elevation and was the same soil series as site 4. Soil tests taken two years after the initial treatment indicated that the fertility level for these two sites was nearly identical. The pHs were 6.7 and 6.8 and P_2O_5 values were 143 and 124 kg/ha. The only apparent difference in the two sites was in past management. Site 6 was unfertile (Table 1) and by observation unproductive at the time the study began. Site 4 was fertile and productive when the study began. Following treatment, productivity increased slightly

TABLE 1. Description of sites where response of permanent pasture to treatment applied according to West Virginia University Soil Test Laboratory recommendations was studied

Site	Soil Series	Elevation (m)	Exposure	% Slope	pH	Available P_2O_5, kg/ha	Available K_2O, kg/ha
1	Gilpin-Upshur	445	East	30-40	5.4	14	228
2	Dekalb	616	East	10-20	4.8	20	228
3	Philo	594	Level	0-3	6.5	60	270
4	Berks-Weikert	622	Southwest	20-30	6.5	63	350
5	Chavies	646	Level	3-10	5.9	26	203
6	Berks-Weikert	652	Southwest	30-40	5.6	22	139
7	Berks-Weikert	652	Northeast	30-40	5.7	14	147
8	Belmont	838	Northeast	41+	5.5*	22	94
9	Belmont	838	South	30-40	5.3	105	346
10	Dekalb	838	West	10-20	5.4	13	294
11	Calvin	860	West	10-20	5.7	35	249
12	Belmont	982	East	20-30	4.7	4	175
13	Teas	1085	Southwest	30-40	5.1	86	287

*Site not limed due to slope.

TABLE 2. Yields (kg/ha) of check and treated permanent pasture plots when lime and fertilizer were applied according to West Virginia University Soil Test Laboratory recommendations

	1971		1972		1973		1974		1975		Avg's 1971–75	
Site	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated
1	1114	2477	2603	4604	2475	4519	2735	3409	3936	5376	2573	4077[a]
2	2286	3855	3543	7124	3093	4756	2792	4438	5052	3199	3351	4674[a]
3	2971	2825	3931	4185	3624	3924	3649	4172	4340	5201	3803	4061
4	8941	8660	10810	11965	11640	9316	10229	8439	9971	8658	10318	9228
5	2150	2590	3381	4598	3663	4510	3435	3364	3820	3313	3290	3675
6	1739	2198	1796	2453	2975	3417	2864	3086	3147	2859	2504	2803
7	1863	2074	2287	2938	2595	3722	2396	3244	2041	4736	2236	3343[a]
8	2359	3280	5065	6352	4528	5355	3036	3482	2743	3306	3546	4355
9	4234	5034	7404	9042	7050	6671	7606	5363	6923	5932	6621	6408
10	1543	1637	3110	3536	2672	4055	1982	3214	3214	2818	2502	3052[b]
11	4177	5287	6233	6089	5889	6987	4023	7419	4532	4948	4971	6146[b]
12	2592	2846	2464	5836	2785	4948	2485	3903	1900	3578	2445	4222[a]
13	1471	1717	2180	2273	1818	1836	2708	1848	2140	2258	2063	1986
Avg.	2871	3422	4215	5392	4216	4924	3842	4260	4136	4322	3856	4464

[a]Treated and check yields are significantly different from each other, L.S.D. at 5% probability.
[b]L.S.D. at 10% probability level.

at site 4 (1972–74) and then decreased to about the original level. Productivity also increased on site 6, but never reached the productivity of site 4. When treated, site 4 produced about four times as much forage as site 6 during the five years. It would appear that the previous management of site 4 caused the site to produce beyond what might be expected by changes in fertility alone. This higher productivity would indicate that such things as species, soil structure, water-holding capacity, rapid recycling of nutrients, and perhaps other factors might be important in achieving high yields and that for maximum production a number of years is required to get all factors favorable for plant growth.

Sward Legume Content

By far the most prominent legume in productive pastures was white clover. It also was the legume that remained in the swards for the longest period and by the end of the fifth year was about the only one present. Table 3 shows that the percentage of legumes was not consistent among sites or treatments but varied from 0 to over 60%. The highest legume content observed was 63% at site 8 for 1972 when

TABLE 3. Percent legumes (dry weight) in check and treated permanent pasture plots when lime and fertilizer were applied according to West Virginia University Soil Test Laboratory recommendations

	1971		1972		1973		1974		1975		5-yr. Avg.	
Site	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated
1	0	11	1	56	1	32	2	12	0	8	1	24
2	18	33	18	48	17	22	2	14	6	4	12	24
3	11	5	3	4	6	3	10	7	12	6	8	5
4	50	47	43	41	50	41	43	36	32	38	44	41
5	9	16	3	2	5	4	8	4	4	1	6	5
6	0	1	1	2	1	14	9	13	2	8	3	8
7	0	12	0	16	3	16	3	26	0	28	1	20
8	58	54	63	58	16	18	3	8	3	4	29	28
9	14	21	14	13	6	5	6	5	4	2	9	9
10	5	1	9	7	3	7	6	3	3	3	5	4
11	50	57	40	43	41	24	34	13	35	5	40	28
12	0	9	0	29	9	20	0	17	0	14	0	18
13	15	15	13	10	31	18	22	14	13	22	19	16
Avg.	18	22	16	25	14	17	11	13	9	11	14	18

untreated. Site 4, which consistently produced the highest yields, was the only site that averaged over 40% legumes in the sward. The rapid increase in percent legumes at sites 1 and 2 was almost entirely attributed to red clover (*T. pratense* L.) which did not remain in the sward for any appreciable period. Red clover also volunteered at site 8 but was about equal in both the check and treated area. However, the percent red clover dropped rapidly in only two years and accounted for only 3 to 4% of the forage by the end of the five-year period.

Nearly all sites had an increase in percent legumes following the initiation of the study even when no lime or fertilizer was applied. Apparently just the removal of vegetation and repeated clipping was enough to encourage volunteer legumes. This would indicate that grazing pressure might be used to increase legume content and yield in some situations without changing fertility. The period of time necessary for the appearance of legumes varied, but in most cases legumes peaked by the second or third year. A notable exception was site 7, a northeast exposure, which did not reach its peak until the fifth year. Site 10 was the only site where the percent legumes never reached as high as 10% in any year. Nevertheless, this site was more productive than some of the others.

Sites that initially had a high percentage of legumes tended to exhibit a decrease in legume content when protected by cages and clipped. At some sites it was noted that the legume content of the sward was higher in grazed areas than in similar areas protected by cages. The reason may have been that the area was not kept short enough, and light may have been a limiting factor for legumes although five to six harvests were taken on the more productive areas.

Seasonal Distribution of Forage Production

Table 4 shows the distribution of the forage production during the growing season. Only three of the sites produced any appreciable forage during April. They were among the lowest in elevation and had eastern or southwestern exposures which warmed up early.

Treatment increased yields in nearly all cases (Table 1) but did little to change the month in which most of the forage was produced. More forage was produced in May than any other month at 10 of the 13 sites. At sites 8, 12, and 13 essentially as much forage was produced in June as in May. However, these were probably the coolest of the sites due to elevation in the case of sites 12 and 13 and due to exposure at site 8. As a result of the cooler temperatures, the peak period of production was later in the year at these three locations. The data in Table 4 show that over 50% of the forage was produced in the first one-third of the season and at some locations 60% of the forage was produced by the first of July.

At all sites, regardless of the total forage produced, the proportion produced each month was essentially the same for both treated and untreated areas. From this study it would seem that more uniform distribution of forage production during the grazing season cannot be achieved through the application of lime and fertilizer. However, since site 4 produced 10 to 12% of its total forage in April and site 6, which was very similar except for productivity, produced no appreciable forage in April, there is some indication that productive pastures may start growth earlier in the year than unfertile ones and in this fashion extend the grazing season.

TABLE 4. Percent of total yields produced each month (1971–75 average) from check and treated permanent pasture plot

	April		May		June		July		August		September		October	
Site	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated
1	8	10	23	26	20	16	21	17	17	16	8	10	3	5
2	18	16	26	25	14	15	17	16	13	13	8	9	4	6
3			36	33	19	18	16	16	16	18	10	11	4	4
4	12	10	23	22	18	20	15	15	15	15	10	11	6	7
5			39	43	18	16	14	12	12	12	11	11	7	6
6			37	36	24	22	18	18	12	13	6	7	4	4
7			36	40	24	18	16	15	12	13	8	8	5	5
8			25	26	27	26	21	22	15	17	9	8	4	3
9			37	37	19	21	17	17	14	14	9	8	5	4
10			36	35	23	22	16	18	11	12	8	9	6	6
11			27	28	17	15	17	16	18	19	12	13	9	9
12			29	30	30	27	20	17	12	12	5	8	4	6
13			31	31	29	29	22	22	12	12	4	4	3	3
Avg.	3	3	31	32	22	20	18	17	14	14	8	9	5	5

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29.

Effect of Phosphorus, Sulfur and Molybdenum on Subclover-Grass Hill Pasture Yields in Southwestern Oregon, USA

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Coos and Curry counties, located on the south coast of Oregon, have more than 81 000 ha of hill lands suitable for grazing cattle and sheep. Most of this land was once forested with conifers, mainly Douglas Fir. Following logging, the land was burned and seeded for grazing. Through continued burning, and in recent years piling of brush and debris with bulldozers, large areas have been cleared.

Following logging, during the period 1920 to 1950, the land was available at low cost to individuals. In 1963 hill land in Coos County was valued for taxation at $30/ha. Since 1960, the demand for the land has increased, and timber companies are paying over $500/ha for hill land to be reforested.

The climate is mild. Winter temperatures are seldom below 4° C, and the average summer temperature is 16° C. Rainfall averages 127 cm from October to June and less than 12 cm during the remainder of the year. The climate is ideal for subclover-grass pastures grazed 12 months by livestock. A minimal amount of winter feed supplementation for livestock is necessary.

The soils are formed from sedimentary rock. They are well-drained and moderately to strongly acid, with slopes of 0 to 70%. Over 90% of the soils are deficient in P. The soil survey of the area is unfinished.

Yields observed from established subclover (*Trifolium subterraneum*) pastures in the area were noted to be less than expected when P was applied. Yields in other subclover-producing areas greatly exceeded Coos and Curry county yields. This suggested that the soils might be deficient in other nutrients also. The problem was discussed by extension and research personnel, and based on reports from New Zealand and Australia, we decided to investigate the response of southwest Oregon hill pastures to applications of P, S and Mo. Dr. M. D. Dawson, OSU Professor of Soils, Dr. William McGuire, OSU Professor of Farm Crops, the late Arthur S. King, OSU Extension Conservation Specialist, and Dr. E. Hugh Gardner, OSU Extension Soils Specialist, cooperated in the study.

PROCEDURES

The OSU extension soil fertility program coordinated through the Coos County Extension Office included (1) TVA demonstration farms, (2) research projects by Oregon State University Experiment Station researchers and (3) applied research and demonstration trials by county extension agents.

This report is on the applied research and demonstration trials established to investigate subclover response to P, S and Mo. The trials were established from 1965 to 1975 at a number of locations. The results of trials at seven locations are summarized in this report. A randomized block design with three replications was used for all trials. All trials were established in the fall on established stands of subclover with harvest made in mid to early spring using an 0.9 m sickle bar mower with a 5 cm cutting

height. The areas were fenced to prevent grazing. The P and S were applied broadcast and the Mo in a water solution as a spray. Treatments and rates of nutrient application are listed in Table 1. Soils were sampled prior to treatment and chemical analyses of the soils in the seven locations of the trials are listed in Table 2.

TABLE 1. Treatments and rates of nutrient application

Treatment	Rate of Application
Check	No fertilizer
P	22 kg P/ha
PS	22 kg P/ha, 25 kg S/ha
PSMo	22 kg P/ha, 25 kg S/ha, 420 g Mo/ha

TABLE 2. Summary of chemical analysis of soil samples from trial areas

Location	pH	P[a] ppm	K[b] Meq 100g	Ca[b] Meq 100g	Mg[b] Meq 100g	B[c] ppm	CEC[b] Meq/ 100g
Adams	5.2	2.0	0.90	5.6	4.7	0.43	
Geaney	5.4	5.0	0.82	5.9	3.3	0.46	30.6
McKenzie	5.7	3.5	0.61	7.4	4.4	0.54	22.2
R. Waterman	5.5	35.0	0.86	8.7	3.7		
Wahl	5.2	8.0	1.28	6.6	4.2	0.54	
Bethel Creek	5.3	13.0	0.98	4.2	2.5		
C. Waterman	5.5	3.0	1.47	5.4	2.9		

[a]Dilute Acid-Fluoride Method (Bray).
[b]Ammonium Acetate Method.
[c]Curcumin Method.

RESULTS AND DISCUSSION

The combined application of P, S and Mo to subclover hill pastures produced significant increase in yields in each of the seven trials. The yields of air dry forage from the trails are summarized in Table 3.

TABLE 3. Effect of various fertilizer treatments on subclover-grass yields at trial locations

Location	Subclover Yields as Average kg/ha Air Dry Forage for the Respective Treatments Check	P	PS	PSMo
Adams (1972)	504	1 138	2 001	2 803
Bethel Creek (1966)	983	2 139	2 539	3 241
Bethel Creek (1967)	1 796	3 304	3 715	4 921
McKenzie (1970)	2 551	—	3 926	4 463
Ray Waterman (1968)	2 754	—	4 743	6 189
Geaney (1970)	—	4 294	3 398	7 115
Geaney (1971)	—	3 244	2 474	4 827
Wahl (1970)	—	—	570	1 077
C. Waterman (1973)	482	—	1 910	2 935
C. Waterman (1974)	825	—	1 953	2 380
C. Waterman (1975)	500	—	2 722	3 448

Phosphorus

Response to P was measured in the Bethel Creek and Adams trials. Application of 22 kg P/ha increased yields 84 to 125%. The yield increases ranged from 634 to 1508 kg/ha.

Sulfur

Sulfur response was apparent at the Bethel Creek and Adams trials. Yields were increased 13 to 76% from the application of S at 25 kg/ha. The increase in yields ranged from 400 to 863 kg/ha.

Molybdenum

All of the trials responded to the application of Mo. Increase in production from the application of 420 g Mo/ha ranged from 14 to 109%. Yields of air dry forage increased 427 to 2 353 kg/ha in the seven trials.

Molybdenum-Phosphorus-Sulfur

The application of P, S and Mo together gave the greatest increase. This indicated that all three nutrients were deficient for maximum subclover production. Yields were increased 49 to 590% with air dry forage yield increases ranging from 427 to 3 435 kg/ha.

30.

Lime and Phosphorus Response of *Medicago sativa* Seedlings on Low pH Hill Land Soils*

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The hill lands of southeastern Ohio are predominantly acid, requiring both lime and fertilization for satisfactory forage legume production. These soils are generally quite susceptible to erosion, making it undesirable to break the sod or till them in order to incorporate the lime as usually recommended.

Brown (1959) found that banded superphosphate resulted in greater alfalfa (*Medicago sativa* L.) seedling growth than the same amount mixed with the soil. Band-seeding for alfalfa establishment has been recommended for many years and is ideally suited to a no-till planting program.

Soil penetration of surface applied limestone is rather slow (Longnecker and Sprague, 1940) and high rates of lime may result in considerable loss due to surface erosion in hill lands. Liming to a minimum soil pH of 6.0 is essential for satisfactory establishment of alfalfa. Pohlman (1946) found that maximum alfalfa yields were obtained by liming to a soil pH of 6.7. Surface applied lime will affect primarily the surface 2 to 3 cm of soil during the first year. Since soil testing laboratories typically base their recommendations on the 15-cm plow layer, these rates could possibly be lowered by 50 to 66% to minimize limestone losses via surface runoff. These lower rates should still be sufficient to neutralize the upper 5 cm and subsequent applications would be necessary to maintain a desirable soil pH.

No-till planting of forage legumes requires a modification of common soil amendment practices on acid soils. Since lime cannot be readily incorporated into the soils, acid-forming fertilizers such as triple superphosphate will likely increase the effective acidity of the microenvironment of the developing seedling. Greenhouse experiments were, therefore, designed to examine the effect of the source of P and the time of lime application on the seedling growth of alfalfa and the microenvironment soil pH.

MATERIALS AND METHODS

Undisturbed soil cores were taken from a Gilpin silt loam (Typic Hapludult) with a golf green cup cutter and placed in 11.5 × 10-cm cardboard containers. The initial soil pH was 5.0 with 4 kg of available P_2O_5/ha. The recommended lime rate was 13 MT/ha. Soil cores from this site were used in two greenhouse experiments.

The first experiment compared the time and method of lime application on the seedling development of Thor alfalfa. The equivalent of 13 MT/ha of lime was applied at six weeks, three weeks, and immediately prior to seeding. The methods of lime application were banded, broadcast and thoroughly incorporated. The banded lime was applied in a slot approximately 1 cm wide and 4 cm deep across the pot. A control treatment without lime was included. All treatments were replicated six times with three replications harvested six weeks after seeding and the remaining replications harvested ten weeks after seeding. A solution of KH_4PO_4 (equivalent to 100 kg P/ha and 100 kg K/ha) was applied to all treatments in a band below the seed immediately before the seeding. In the banded lime treatments the KH_4PO_4 and seed were banded. One week after seeding, all treatments were thinned to a uniform population of ten seedlings/container.

The second study involved a 2 × 3 factorial with three replications. Treatments were: no lime vs. lime (13 MT/ha) each with three P treatments: no P, 600 kg of $Ca(H_2PO_4)_2$/ha = 174 kg P/ha, and 600 kg of rock phosphate/ha = 4.4 kg available P/ha and 46 kg of total P/ha. All P treatments were applied in a band at a depth of 2 cm, with the seeds planted over the fertilizer band at a depth of approximately 3 mm. The lime treatment was broadcast uniformly across the surface. All treatments were harvested 11 weeks after seeding.

Soil cores were taken with a 1.5-cm probe at each harvest for pH analysis. All pH determinations were made in a 1:2 (soil:water) suspension.

RESULTS

Greater alfalfa seedling growth was observed when lime was applied prior to seeding (Table 1). The treatments with incorporated lime exhibited an undesirable surface structure, resulting in relatively slow water percolation due to surface crusting. Thus the surface of this treatment tended to remain somewhat saturated much of the time.

With the banded lime, seedlings on or near the band grew very well, whereas those more distant from the band made little growth until the root system reached the treated area. An increase in

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TABLE 1. Alfalfa seedling growth response to limestone (ten weeks after seeding)

Limestone Application Time	Method	Shoot Weight (mg/pot)	Root Weight (mg/pot)
Disturbed control		705 ef[a]	845 cd
No-till control		93 f	77 d
At seeding	Incorporated	2 178 abc	2 243 a
	Banded	1 383 cde	810 cd
	Broadcast	2 520 ab	1 508 abc
3 weeks before seeding	Banded	1 684 bcd	971 bcd
	Broadcast	1 309 cde	852 cd
6 weeks before seeding	Incorporated	954 def	972 bcd
	Banded	736 ef	318 cd
	Broadcast	2 628 a	2 132 ab

[a]Means followed by the same letter within a column are not significantly different at the 5% level.

growth rate was noted for the seedlings more distant from the lime band between six and ten weeks after planting.

Nodulation was very responsive to the different lime treatments (Table 2). Incorporation of lime provided a uniform distribution of nodules about 3 mm in diameter throughout the root system. Broadcasting lime resulted in a large cluster of nodules at the crown with very few nodules on the rest of the root system. Banding lime resulted in a chain of nodule clusters along the tap root throughout the extent of the lime-band region (from the surface to about a 4 cm depth). With the no-lime treatment there were very few, if any, nodules present and the seedlings were generally chlorotic. The penetration of lime below the surface 2–3 cm was quite minimal except when the lime was placed below the surface by banding or complete soil incorporation.

TABLE 2. Effect of time and method of limestone application on soil pH and alfalfa seedling nodulation (six weeks after seeding)

Limestone Application Time	Method	Soil pH 0–2.5 cm	Soil pH 2.5–5 cm	Nodulation Rating (0–10)[a]
Disturbed control		6.2	5.5	3.3 de[b]
No-till control		5.2	5.0	0.3 f
At seeding	Incorporated	7.2	7.3	7.7 a
	Banded	6.3	5.1	4.7 bcd
	Broadcast	6.0	5.4	5.7 abc
3 weeks before seeding	Banded	6.4	5.6	4.3 cd
	Broadcast	6.0	5.3	6.0 abc
6 weeks before seeding	Incorporated	7.1	7.2	7.3 a
	Banded	6.7	5.2	2.0 ef
	Broadcast	6.2	5.3	6.7 ab

[a]Nodulation rating scale 0–10, 10 = best.
[b]Means followed by the same letter are not significantly different at the 5% level.

In the second experiment, banding of calcium phosphate depressed alfalfa seedling growth compared to the control or no phosphate treatment (Table 3). Liming alone did not significantly increase the yield, but did overcome the seedling growth depression caused by the application of calcium phosphate.

TABLE 3. Effect of lime and source of phosphate on alfalfa seedling growth

Treatment	Application Rate	Seedling Weight
		(mg/pot)
Control	——	111 bc[a]
Limestone	13 MT/ha	297 bc
$Ca(H_2PO_4)_2$ (29% avail P)	600 kg/ha	21 c
$Ca(H_2PO_4)_2$	600 kg/ha	
+		1 152 ab
Limestone	13 MT/ha	
Rock phosphate (1.3% avail P – 13.6% total P)	600 kg/ha	1 819 a
Rock phosphate	600 kg/ha	
+		2 144 a
Limestone	13 MT/ha	

[a]Means followed by the same letter are not significantly different at the 5% level.

Soil pH analysis of different zones within the calcium phosphate treatment showed a slight drop (to pH 4.7) in the immediate application zone. This did not occur with rock phosphate. Presumably as a result of this difference, rock phosphate with or without lime resulted in superior seedling growth at the end of the 11-week period.

DISCUSSION

The data strongly suggest that for good alfalfa establishment on acid soils, pre-planting surface lime applications are superior to applications at planting. This was expected based on the lime movement studies reported by Longnecker and Sprague (1940) in which minimal penetration of surface applied lime occurred after three years of incubation. Due to this slow penetration of surface applied lime, banding lime may prove to be a useful alternative in a "once over" pasture renovation program. Nevertheless, seedling response to broadcast lime indicates the overall advantage of broadcasting at least a portion of the required lime on the surface.

In these greenhouse experiments most of the surface applied lime was still visible on the surface

16 weeks after application despite the liberal irrigation program. In earlier field experiments at the same site from which the soil cores were obtained, there was no significant difference in soil pH in the upper 5 cm of soil between surface applied lime at the recommended rate and at one-half the recommended rate (Webel, 1976). This is understandable since lime recommendations are commonly based on neutralizing the entire plow layer, whereas the neutralization of the surface 2–3 cm is all that typically occurs during the first year after a surface application of lime (Fig. 1).

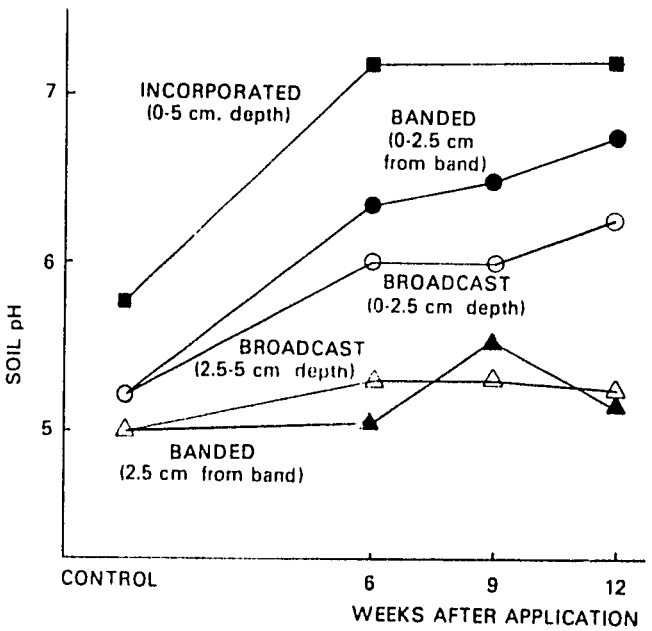

Figure 1. Changes in soil reaction (pH) related to limestone application method and time.

On hill land, surface application of large quantities of lime may be somewhat wasteful due to the potential surface runoff. Thus, annual or biannual applications of 25–33% of the total recommended lime rates would likely be utilized more efficiently in neutralizing the soil acidity under hill land conditions.

Acid-forming fertilizers such as $Ca(H_2PO_4)_2$ or triple superphosphate can be quite detrimental for the establishment of alfalfa due to the decreased soil pH in the seedling microenvironment. Even with the higher level of available phosphorus in triple superphosphate, the rock phosphate resulted in greater seedling growth. In an earlier field study, triple superphosphate treatments on this same soil were essentially void of any legume seedlings; however, rock phosphate treatments resulted in satisfactory seedling stands with and without the application of lime. Without lime, however, the seedlings were lost during the dry summer months.

The use of non-acidulated rock phosphate in acid soils shows distinct promise in a no-till pasture renovation program. Under acid soil conditions sufficient phosphorus can be released to support initial seedling development prior to any effective pH increase due to the surface applied lime. Higher application rates of rock phosphate should be used to compensate for the lower phosphorus availability.

Placing the lime in a band below the surface will decrease potential surface runoff problems but the mechanics of seeding directly above the band will require the development of new machinery for banding the lime. Also, the large quantity of lime required for correcting the soil reaction makes it impractical to lime, fertilize and seed in one operation under most acid hill land situations.

With no-till alfalfa seedings in acid soils, neutralization of soil acidity as well as adequate fertilization are prerequisites for satisfactory stands. The most practical method for correcting the soil pH continues to be a broadcast application during the season prior to renovation (6 to 12 months), with periodic lime applications thereafter as determined by soil pH analysis.

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DISCUSSION

Unidentified. I noticed that nodulation followed the pH level. At what pH will the plants effectively nodulate? Also, did you examine for manganese and aluminum toxicity at a pH level of 4.9 to 5?

Henderlong. We did not examine the manganese and aluminum toxicity problem in this particular study. In response to your question on pH for good nodulation, it appears to be around 6.5. Although I am not a soil microbiologist, the optimum range for nodulation is generally accepted to be 6.5 to 7.0. I think we more nearly approach that pH with the banded lime application treatment than with the other applications in the seed microenvironment of the young developing root.

R. Singh (West Virginia, USA). Did you determine exchangeable aluminum in the original soil? What percent of the CEC was saturated with aluminum? When you see the root system it appears that you put the lime on the surface and the root has not developed properly. Is this aluminum toxicity a lack of calcium or what?

Henderlong. I am sorry that I cannot give you the exact figures, but it was a Gilpin soil, extremely low in exchangeable aluminum. Mr. Webel's thesis does have the other pertinent soil analysis, and based on that information and the percent base saturation, we do not feel that it was either an aluminum or manganese problem.

Unidentified. Were rock phosphate and limestone mixed together and then incubated? Is this how this was done in getting the yield you just showed on the last slide?

Henderlong. The limestone was applied to the soil, distributed, and mixed in with approximately the upper 2.5 cm of soil. A thorough job of mixing was difficult because of the vegetative residue present. The rock phosphate and the calcium phosphate were applied in a band directly below the seed.

Unidentified. Was the amount of lime that you banded the same amount that you put on the complete plot? In other words, was the amount that you banded in a concentrated form comparable to the broadcast applications?

Henderlong. Yes, the lime was weighed and distributed uniformly or mixed in uniformly, respectively, for both methods.

31.
The Challenge and Threat of Tourism Among the Eastern Cherokees

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Tourism among the Appalachian Cherokees poses a paradoxical dilemma for these people not only economically but culturally and psychologically as well. Rapid changes which have occurred since World War II have drastically altered the lifestyle of these once isolated and conservative American Indians. These changes have resulted in increased physical and mental health problems among the Cherokees (Tribal Report, 1976). At the same time, the changes resulting from their new tourist role have brought about technological advantages once unknown to the Eastern Cherokees.

Most observers have realized that some chaos must accompany any sudden social change, and that the ensuing "amonic" situation of cultural normlessness is traumatic for many members caught up in this transition (Durkheim, 1968). Moreover, this type of transition is confusing to societal members when it involves movement from a folk to an urban society or vice versa, Cambodia representing an interesting contemporary example of the latter. The Cherokee transition, however, was one from a traditional folk culture to that of the dominant United States industrialized society. The Eastern Cherokees did not readily fit the general assimilative model according to which other ethnic groups have merged or been assimilated into the larger American culture.

There are two reasons why the Appalachian Cherokees were different. First, the Cherokees did not choose to fully assimilate themselves into the larger white culture, a situation compounded by their distinctive physical and cultural differences. Second, the overall Southern Appalachian development plan was devised in such a manner as to utilize the Cherokees' Indian heritage as a major attraction to this area. Apparently few, either Cherokee or white, envisioned the complexities involved in this unique experiment in cultural adaptation. Ostensibly, the link between land-use and cultural traditionalism escaped the scrutiny of the park planners, the white developers and the tribal leaders. Today we find that a relationship exists between the modification of land use and the diminishing of the Cherokee's traditional heritage and this caused the emergence of new social problems on the Qualla Boundary, as a major section of the eastern reservation is called.

Perhaps the most critical problem facing the Cherokees today is land management. This in turn reflects the larger issues surrounding the transition from the old agrarian folk society to that of a contemporary

industrialized society, represented for the Cherokee by the tourist industry. Even though the Cherokees once claimed millions of hectares of territory, today they have title only to their 22 600-ha reservation. Much of this land consists of mountains, with only 10% suitable for agriculture. Here some 7 000 enrolled Cherokees live, while another 1 000 or so live adjacent to tribal trust lands. In the past this land sufficed in maintaining the Appalachian Cherokee population mainly because of cooperative agricultural endeavors. But the proportion of agricultural land has diminished since the advent of the tourist industry, with just over 1% of the land now so used. To illustrate, during the four-year period 1966–70, 269 ha of agricultural land was taken out of production, leaving only 286 ha for farming (Cherokee Comprehensive Plan—Vol. 1, 1976).

This cultural transformation has led to new problems, one of the most significant being poverty. The Indian Agency Social Service Department describes the situation as follows:

> This area of Appalachia has been a pocket of poverty since the time it was settled. As late as 1960, the per capita income of the six Western North Carolina counties was $836 as compared to $1,169 average for the state and $1,901 for the nation. The Indian's plight was considerably worse even in this depressed area. In 1958 the average family income was estimated at $600 annually or some $200 less than the per capita income in the surrounding area which was little more than half as much as the national level. In 1958, 140 families had less than $300 cash income per year. The years 1955 to 1959 saw the Cherokees reach the lowest ebb in economic deprivation. Practically no employment was available during the winter months and in addition the boarding schools had closed and the children were in their homes the year-round for the first time in many years of Cherokee history. Prior to 1940, some employment was available in the logging industry, but this was drastically decreased due to the establishment of the Smoky Mountains National Park. During World War II, the war economy prevented mass deprivation but by the end of the War, the Cherokees were actually suffering. After World War II, while the nation prospered, conditions of the people of the Cherokee Reservation and the counties surrounding it continued to decline.

The same federal agency also states that tourism has had an adverse effect on the Eastern Cherokees:

> The problems encountered when an Indian attempts to move from extreme poverty and an agrarian way of life to a money economy are awesome. Added to this transition, the Cherokee feels keenly the on-slaught of the dominant Anglo culture compounded by over eight million pleasure-seeking tourists each year who invade his reservation and gawk at him as the Native American. The astute Cherokee obliges for economic reasons and with tongue in cheek he dresses in feathers, dances, sells Indian-made artifacts (or Japanese-made Indian artifacts), prepares food, serves food, and generally entertains the visitors. It is however, an affront to his way of life and although his economic situation is greatly improved, this rapid change in economy and culture has not been attained without a price—one of which is excessive use of alcohol and the resulting problems of broken families, children living away from their natural parents, crime and delinquency, etc. (Cherokee Health Evaluation Report, 1975: 30).

A conservative estimate of Cherokee poverty places it 38% above that of the state of North Carolina and 38.24% higher than the national average. Accordingly, 55% of the Cherokees live below the poverty level. Others feel that over 80% of all Cherokee families live below the poverty level of $3 000 per year. (Cherokee Health Evaluation Program, 1975).

Other social problems have resulted, especially during the past fifteen years when tourism made its greatest impact upon the Qualla Boundary, which comprises the largest proportion of the reservation. Among the Cherokees, alcohol-related problems have always been a social issue, but more recently public drunkenness has emerged as a serious situation (French, 1975). In the past most drinking pathologies occurred in the privacy of the family or community setting, far from public view. And while this isolated form of drinking still exists among the more traditional Cherokees, public drinking is a relatively new phenomenon among the Eastern Cherokees which corresponds closely with the advent of the tourist industry. In fact, public drunkenness, driving while intoxicated, and public brawling while intoxicated are examples of behavior that was taboo according to the traditional Cherokee ethic, which is opposed to public or overt expression of behavior, especially emotional behavior.

Similarily, criminal assault has increased, as well as breaking and entering, larceny, truancy and disorderly conduct. In addition, about 1 500 mental disorders are reported annually (Cherokee Health Report, 1975). This and other health problems suggest the prevalence of social, cultural and psychological confusion among the Cherokees during this transitional period. Major health problems include diabetes and hypertensive disorders which affect a third of the tribal population (about 1 500 Cherokees),

while diseases of the circulatory system and overweight afflict an even larger number of them. The Cherokee Public Health Service records some 30 000 hospital visits a year including over a thousand lacerations and nearly three times that number of other entries related to accidents, poisoning or violence. These social problems, in turn, have led to a higher proportion of broken homes, with many (416) Cherokee families having a female head-of-household.

METHODOLOGICAL NOTE

Only descriptive analysis of the data is possible due to the difficulty in obtaining first-hand data from the Bureau of Indian Affair's Indian Health Service in New Mexico. All Indian health data are kept in Albuquerque and it has only been within the past few years that these data were categorized according to basic demographic standards, i.e., age and sex. Unfortunately, this information is difficult to obtain and has been unavailable even to tribal officials who need it for preparing grant proposals and to evaluate existing programs as well as to project future needs.

CHEROKEE TRADITION IN TRANSITION

The forced removal of 1838 divided the Cherokees into three distinctive geographical groups: Oklahoma, Texas and North Carolina. Initially the North Carolina or Appalachian group consisted of about 1 000 Cherokees in comparison to the current 8 000 population. Eventually this group became known as the "Eastern Band." These Indians were some of the most conservative of the old Cherokee Nation, opposing most of the progress made by this Indian group during the early 1800's. The Appalachian Cherokees seemed content on continuing the old cultural lifestyle undisturbed by either the new progressive Cherokee culture or by attempts toward acculturation. Their original land holdings included most of what is now east Tennessee and Western North Carolina, but a treaty condition requiring all Appalachian Cherokees to "deed" their tribal holdings as individual land holdings and to become citizens of North Carolina, led to the eventual loss of most of their regional lands. A long legal battle ensued, following the Civil War, concerning trust land obtained for the Eastern Cherokees. Apparently their lawyer, a local white named Will Thomas, did not keep accurate records of these transactions and it was not until 1975 that the land issue was finally resolved. Today the Eastern Cherokees have land scattered over four North Carolina counties and a small island which was recently presented to the tribe by the state of Tennessee. The single largest land tract is the Qualla Boundary located in Swain and Jackson counties. All told, the reservation consists of some 22 600 ha which has been held in federal trust since 1925. The period of trust is 25 years, at which time the tribe votes on whether to continue the pact for another period. The current period ends in the year 2000. Other land surrounding the reservation is deeded, being owned by Cherokee Indians. This land is not considered part of the tribal holdings.

Much like their aboriginal ancestors the early Cherokees were farmers, augmenting agriculture with hunting, fishing and the gathering of wild herbs, nuts and plants. They survived and seemed content in maintaining the old Indian lifestyle isolated from the rest of American society. For decades Southern Appalachia was a haven for mountain whites and Cherokees who preferred to be left alone to pursue their respective lifestyles. But increased federal and state intervention brought pressure to bear upon the Appalachian Cherokees to alter their traditional lifestyle. This and the advent of the railroad, used initially for mining and logging industries, served to open up Appalachia to outsiders. Yet, for the most part, the mountains remained an effective barrier against outsiders. Access roads were poor and services and accommodations few. Politically and economically southern Appalachia was viewed as low-value real estate, therefore little consideration was given to it.

Perhaps the initial factor leading to the change in the Cherokee culture was the state's effort at taxation. Prior to the imposition of state taxes the Cherokees operated cooperative farms under the management of a family network known as the Gadugi. This kinship-based mutual aid society made best use of the rugged terrain with fields, gardens and orchards dotting the Qualla Boundary and each family dividing the labor accordingly. This agricultural system came to an abrupt end when North Carolina began to tax the Gadugis as corporations. The decline in the self-sufficient cooperative lifestyle of the Cherokees was reinforced with the advent of federal aid which made a significant impact in 1925 when the U.S. assumed trust responsibility for the Eastern Cherokees. Moreover, once institutional dependency replaced the traditional mutual-aid agricultural cooperatives, other mutual aid endeavors (logging, fishing and hunting) were forsaken as well. This was surely the beginning of the transitional period with the advent of independent, secondary institutions staffed mainly by non-Indians and providing services which were once handled by the extended family network and local community. Some jobs were provided by the logging industry, but these ended during World War II when environmentalists sought to protect the remaining Southern Appalachian vegetation for the public's enjoyment.

Certainly the most significant factor during this transitional period was the development of the Great Smoky Mountains National Park. It was originally conceived in 1899, but was not dedicated until 1940.

Approximately one-third of the 200 000-ha park was primeval when the idea was first discussed, but extensive logging of land once owned by the Eastern Cherokees greatly diminished the proportion of virgin wilderness. By 1940, 18 timber and pulpwood companies owned 85% of what is now the park. The remaining 15% was divided among 1 200 mountain farms plus 5 000 summer homesites and lots. In all, there were 6 601 separate landowners to contend with, 401 in North Carolina and 6 200 in Tennessee. Tennessee landowners mostly owned summer camp lots, 1 000 of which were sold in 1931 at a Knoxville movie house promotional contest. The first land bought for the park was the 13 200-ha Love Speculation, land which the Eastern Cherokees sold to a prominent local white who logged it before placing it back on the market. In 1899 this land was set aside for the park. In 1933, North Carolina and Tennessee transferred Appalachian land to the federal government for the purpose of the park, and this, along with a $5 million donation by John D. Rockefeller made our nation's 22nd national park a reality.

The original park planners realized that the Eastern Cherokees would have to play an important role as a tourist attraction in this otherwise isolated part of the Southeast. The park, the Tennessee Valley Authority's complex of mountain lakes, and the road building program during the Great Depression were all designed to provide easy access recreation for the populous eastern United States which lacked any sizable recreational facility at that time. In this original plan the Cherokees were prepared to play the "movie-Indian" role designed to attract tourists to the area. Considerable effort was required for this drastic cultural transformation to occur. In essence, the Eastern Cherokees had to exchange their unique cultural lifestyle and self-maintained isolation for a false Indian image and congestion during the tourist season. Three institutions were responsible for converting the Eastern Cherokees: The Bureau of Indian Affairs, the National Park Service and a newly organized group of local businessmen and politicians known as "The Western North Carolina Associated Communities." The success of their joint effort is readily evident with advancements in certain areas of the reservation such as new schools, churches, homes, roads, shops, motels, stores and restaurants. Furthermore, eight million tourists visit the reservation during the six-month season (April–October). Most of them also visit the adjacent Great Smoky National Park, thus making the Qualla Boundary the most visited Indian reservation and the Great Smoky the most visited national park in the country.

THE CYCLIC IMPACT OF TOURISM

Generally speaking, this success has not been without social problems which seem to be directly related to the success of the tourist industry, and one of the reasons for this is the cyclic nature of the tourist industry. For six months Cherokee is flooded with the onslaught of millions of tourists only to be transformed again into an isolated rural Appalachian community during the offseason. Hence, many Cherokees come to suffer an adjustment problem and this is evident in the increasing proportion of "marginal" Cherokees. Prior to tourism most Cherokees lived a rural farm existence much like their ancestors. But today their land holdings are far more valuable for tourist enterprises, thus farming has fallen off considerably, so much so that now they are classified as being "rural non-farm" (Tribal Report, 1976). The changing value of this once low-value land now has a magnetic attraction to those millions who find the combination of American Indians and these beautiful mountains an aesthetic portrayal of American beauty. But land which houses motels and tourist shops cannot be farmed and many Cherokees who would like to farm, as they did in the past, cannot because of the encroachment of the tourist industry.

Some Cherokees have adapted to this situation. They comprise a small elite known as "middle-class" Indians. Yet most of the tourist industry is not run by the Cherokees but by non-Indians who lease property either from the tribe or from individual Cherokees. These white businessmen and the middle-class Cherokees constitute their own separate social circle on the reservation.

The remaining Cherokees are torn between these two worlds—their traditional heritage on the one hand and the affluence of the middle-class Cherokees on the other. In addition, they are not certain what is expected of them either from their own people or from the larger dominant society. They see the movie-Indian image being rewarded by the tourist during the tourist season and yet they learn of an entirely different cultural heritage from history and from their traditional brothers and sisters. Although this increasingly large class of marginal Cherokees is a direct consequence of tourism and poses a serious threat to the continuation of the unique Eastern Cherokee cultural heritage, few anticipated this dilemma and few know how to handle it today. This, more than anything, is the real challenge facing this part of Southern Appalachia. For few would question the relationship between the stability of the Eastern Cherokees and the continued success of the Great Smoky Mountains National Park. If one fails, then so will the other, and in this respect a large portion of America will suffer as well (French, 1975).

Currently some effort is being made to resolve this issue. The Cherokee Historical Association has built a $1 ½ million Cherokee Museum whose purpose is to preserve the original Cherokee culture. In addition, the Cherokee language is again being

taught, this time in the Cherokee schools. Arts and crafts guilds have been formed among the Cherokee people in an attempt to preserve their skills and to teach them to each other. And they are not alone in their effort; state, federal and private agencies are all helping in this endeavor. Only the future will tell the outcome of the current dilemma, but given the Cherokees' past record they have a good chance to succeed in this challenge in such a way that will be beneficial to all Americans.

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32.
Development Control in Hill Lands

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Within a framework of climatic and physiographic constraints, our use of land is determined by cultural factors. Man adapts to the land, but in the process changes the shape of that landscape in accordance with a system of values and technological capabilities. Imagine what land use patterns in the United States would be had it been settled from the West by Orientals rather than from the East by Occidentals. Laws and regulations governing what land should be used for specific purposes and under what conditions it should be brought into use are elements of culture that have important meaning for those of us concerned with development of hill lands. This paper will look at the means by which various levels of government can enforce standards for development which will not stifle economic growth while protecting the unique environment of hill lands.

In the United States, zoning ordinances and the accompanying zoning maps are the legal tools most commonly used to regulate land use. Zoning is a locally adopted ordinance regulating the use of land and buildings, the density of population, and the height, bulk and spacing of structures. It is usually intended to be the means whereby a comprehensive land use plan is implemented. The zoning concept, however, has several major drawbacks. Foremost among these is the haphazard pattern of its adoption and enforcement. Of some 38 000 units of local government (counties, municipalities, and townships) in the United States less than 10 000 have a zoning ordinance or subdivision regulations (Clawson, 1972). In mountainous areas, I believe the adoption rate is less than the national average of one in four local governments. For example, of 28 counties in western North Carolina, not one enforces a zoning ordinance throughout the county and only the larger municipalities enforce any land use controls. In many politically conservative areas, zoning has been opposed because it is perceived to infringe upon rights of property ownership and because of its big government overtones.

In those areas where a zoning ordinance has been adopted it has not always met with successful enforcement. This limited success is due to a variety of reasons. First, a zoning ordinance places the burden of proof on the enforcing authority. That is, rather than the developer defending, say, a change in zoning district boundaries, the local government must prove the change either detrimental to the community's environmental quality or inconsistent with an adopted land development plan. Second, enforcement of the ordinance is left entirely to units of local government often unequipped and unenthusiastic about enforcing controls unpopular with voters. Third, the zoning map often overzones land for uses thought to be economically desirable, e.g., industrial districts. This attitude implies that a superabundance of poorly situated sites will serve in lieu of a smaller number properly prepared, serviced, and situated.

A fourth reason for the failure of many zoning ordinances is that the zoning districts often have little relation to the physical geography of the landscape. Except in the few cases where free-standing new towns have been built, zoning regulations are superimposed on an existing world. Because "grandfather" clauses form a part of a state's enabling legislation, the existence of a land use is taken to be justification for its expansion. Commercial land uses breed adjacent commercial uses even if severe environmental damage must be tolerated in the process. Finally, zoning ordinances have been incorrectly used to achieve certain social objectives. State and federal courts, however, have rejected ordinances that, by design, exclude certain economic classes through large lot requirements or by severely limiting availability of multifamily housing.

The shortcomings of zoning enforcement do not preclude the desirability of development control in hill lands. Rather, a different approach is called for. I would suggest a system of performance standards be applied to any development which exceeds certain environmental impact thresholds. Generally, performance standards establish a set of criteria against which the impact of a proposed development is measured. If the impact score falls within a tolerable range, the development—regardless of its specific land use—may proceed. Specified cutoff points may be set to group similar scores. Individual dwelling units or other minimal impact uses may be exempt or subjected to a different set of standards. The uses of land, then, became separated into categories not from an arbitrary list as in a zoning ordinance, but by grouping uses having similar performance standards.

Selection of the performance standards is of key importance to effect such a program. The selection process, however, is beset with many problems. The criteria must reflect awareness and concern for local topography; they must be capable of assessing short-term and potential long-term environmental damage; and finally they must be articulated in a reasonable manner. Unlike air or water pollution abatement standards, land use regulations have no established base universally seen as ideal. The performance goals sought by enforcers of standards must be stated concretely or risk being declared arbitrary by the courts.

Accepting these caveats, a set of performance criteria (Healy, 1976) may require assurances from the developer that the proposed project:

1. Will not result in undue water or air pollution.

2. Has sufficient water for its reasonably foreseeable needs and, if existing water supplies are to be used, will not cause an unreasonable burden on the system.

3. Will not cause unreasonable soil erosion or reduction in the capacity of the land to hold water. This criterion is critical on forested slopes, especially those exceeding 15%.

4. Will not cause unreasonable highway congestion or will not create conditions unsafe to pedestrians or motorists.

5. Will not place an unreasonable burden on the ability of the local government to provide governmental services including education.

6. Will not have an undue adverse effect on the scenic or natural beauty of the area, historic sites, or rare and unreplaceable natural areas. (Since many hill land areas are centers of recreation this criterion may be vital.)

7. Is in conformance with adopted local, regional and state land development plans.

The list of performance standards creates a framework within which the decision-making process can take place. Some criteria are amenable to statistical analysis, e.g., water and air pollution, while others require a review procedure, in fact, an adversary procedure, to decide whether to issue a permit for the project. This process will require the participation of, and cooperation between, various levels of government.

In 1974, legislation was proposed to the North Carolina General Assembly to establish a Mountain Resources Commission (M.A.M.A. 1973). The 11-member Commission appointed by the governor was to play a major role in administering a mountain area management system for western North Carolina. The bill establishing the Commission was defeated, in part, because the Commission was seen to be too far removed from the problems of local government. On the other hand, the relative success of Vermont's Environmental Control Act of 1970 (Act

250) can be attributed to the use of district commissions to review development plans and a de-emphasis of the state role in this review process.

In light of these experiences and the lackluster history of zoning enforcement at the local level, it appears that enforcement of a system of performance standards should not be left entirely to either local or state government acting alone. A compromise structure incorporating district commissions working within a general framework provided by state government is appropriate. These general guidelines could use the recent British experience with structure plans as a model.

Structure plans are statements of general policy, showing trends and the broad patterns of future development. They consist mainly of a written statement with appropriate diagrams, but do not show proposals in detail. Action areas, i.e., areas selected for comprehensive development in accordance with a detailed plan to be prepared subsequent to the structure plan, are shown (Clawson and Hall, 1973). Detailed proposals are prepared by the local authority in accordance with the general policies set by the structure plan.

State government working in cooperation with regional councils of government could be responsible for preparing structure plans for mountainous areas. The structure plans should contain a detailed list of performance criteria to be met before a permit is granted for any major development. Local governments working with the regional councils could then prepare detailed development plans for their political jurisdiction. It should be emphasized that these plans need not be colorful cartographic expressions of desired land use patterns. They could be a refined set of policies with which the unit of local government states will guide their land-planning decisions. Local plans or policies would implement the general policy guidelines of the structure plans. District commissions consisting of persons with expertise in some aspect of development, planning or ecology appointed by the local governments could be established to review applications for development within the region. The commissions should serve an area covering 30–35 units of local government and at least 100000 population. Appeals from the judgments of the district commission could be made to a state-appointed review board then to the court system. In cases brought before the district commission, the local governments directly concerned with the proposed development may act in an adversary role with the developer. In this manner, local interests are served while regional and state concerns are also protected.

The experiences of enforcing Vermont's Act 250 have shown performance standards alone are not capable of regulating land use. Developments affecting less than ten acres inside a town having zoning and subdivision bylaws are exempt from the Act. More importantly, the Act might impose restrictions on design and layout and set standards for reducing soil erosion during construction, but it did not tackle the problems of growth itself. Growth management tools were left largely to a capital gains tax on land sales and forms of property tax relief for allowing land to remain undeveloped.

Although the review procedure outlined herein is not a panacea for controlling development of hill lands, it does offer an alternative means of regulation. Proposed industrial or any other land use would be judged against a series of objective criteria rather than the subjective appraisal of many zoning decisions. Performance criteria could serve as a feasible guide for decision-makers.

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33.
Social Adaptation to the Mountain Environment of an Andean Village

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Over the past several years it has become increasingly apparent that social adaptation to a complex eco-setting is of fundamental importance to understanding central Andean society. The native civilizations of this area evolved in the context of this environment. The contemporary Quechua- and Aymara-speaking inhabitants of the highlands continue—albeit with modification—many of these aboriginal ecological adaptations. Consequently, a knowledge of contemporary adaptations can elucidate the process of state formation in this area (Mitchell, 1976a, 1976b). Moreover, since these ancient civilizations were primary states, i.e., they evolved independently of other states (Lanning, 1967; Lumbreras, 1974; Patterson, 1973), the knowledge gained will increase our understanding about the evolution of civilization in general.

The central Andes is characterized by three broad geo-environmental divisions: the desert coastal plain, the semi-arid highlands, and the montaña or tropical rain forest of the eastern Andean slopes. In addition, each of these regions is diversified internally. Of particular interest in the evolution of Andean society is the ecological setting of the highlands. Here a large sampling of the world's major ecological zones is arranged vertically along the mountain slopes. Within a short span one may travel from a warm sub-tropical valley to a cold alpine tundra.

A major focus of recent research has been the study of a unique and important feature of the Andean adaptive pattern known as the exploitation of vertical archipelagos (Murra, 1968, 1972). In this adaptive strategy, aboriginal civilizations maintained political control over discontinuous areas in different eco-zones, sometimes separated by several hundred miles, in order to exploit the products of these zones. Our knowledge of this pattern has been extensively documented by Murra's ethnohistoric research. Although found in a diminished way in many local communities today, where for example, highland communities possess parcels of land in the tropical forest montaña, the most complex manifestations of this adaptive pattern disappeared after the Spanish conquest (Fonseca, 1972).

A separate, although not exclusive, adaptive strategy in the highlands has been the exploitation of vertical eco-zones found over a continuous area. This pattern persists in many contemporary communities (Gade, 1975; Mitchell, 1976a, 1976b; Rhoades and Thompson, 1975; Thomas, 1973; Arnold, 1975; Brush, 1976; Custred, 1973; Fonseca, 1972; Vallee, 1971; Webster, 1971). In some cases the number of eco-zones exploited is very few, while in others it is quite extensive. However, the extent of the relationship between the vertical ecology and the organization of a contemporary local community has only begun to be intensively documented. This paper represents a preliminary step in this direction by focusing on the role of altitude-determined environmental zones in the organization of Quinua, a community in the central Peruvian highlands. For reasons of space, much of the argument is presented in outline. More detailed reports are in preparation (Mitchell and Arnold; Mitchell). Nonetheless, as will be explicated below, the data from Quinua indicate that land use and productive organization are directly related to the mountain ecology. Land use, in turn, affects such social features as land tenure, settlement pattern, population density, barrio organization, and social stratification.

LOCATION AND SETTING

Quinua is a Peruvian district located to the northeast of the city of Ayacucho on the western slopes of the range of mountains forming the eastern wall of the Ayacucho Valley (Fig. 1). The elevation of the central town is slightly less than 3 396 m. The town is located at latitude 13°03′ and longitude 74°8′. The topography of Quinua, as in much of the highlands, consists of gentle slopes interspersed with numerous deep and rugged ravines and gorges. These provide drainage during the rainy season. Cultivated terrain is generally found on the slopes, although land may be sown at the bottom of some of those larger ravines which do not flood during the rainy season.

Quinua consists of a central town, surrounded by rural hamlets and dispersed settlements. The town is the administrative and ceremonial center of the district. In addition, the district is divided into geo-political units or hamlets known as *pagos*. The center of a hamlet is usually a small nucleated village. In addition to its center, every hamlet is divided

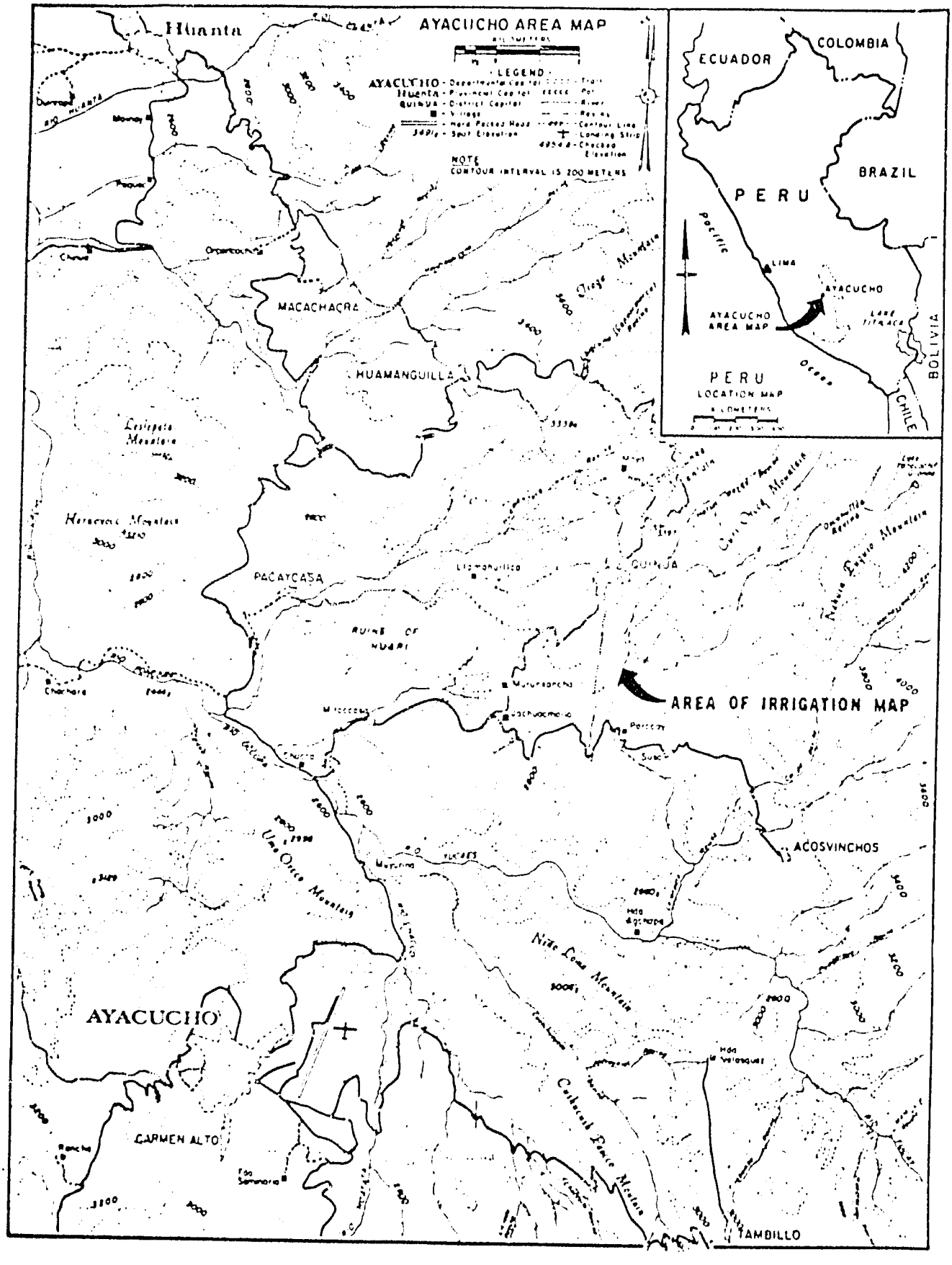

Figure 1. Quinua and Ayacucho Valley.

into localities (*sitios*) that pertain to it for administrative purposes. Hamlets and localities are usually delineated by features of the terrain such as ravines and steep mountain slopes.

Quinua is an independent community (i.e., relatively free of hacienda control) in which most people own their own lands. Except for a small ruling group of townsmen, and recently educated young people, most of the population of 5348 people consists of Quechua-speaking peasants (*campesinos*) (Mitchell, 1974).

The people of Quinua are subsistence farmers. Only a few people, mostly government workers, have no farms or animal herds. Craft production is a part-time specialization and even most of the merchants rely on their own agricultural production for subsistence. Although everyone sells surplus crops from time to time, only a few townsmen produce cash crops in any regular way. Nonetheless, people ordinarily do not produce all the food that they consume. As will be discussed below, agricultural production is directly related to the mountain ecology, in which each eco-zone specializes in particular foodstuffs. Although Quinuenos try to have fields located in several eco-zones, they are never able to achieve complete self-sufficiency (Fonseca, 1972). Consequently, even within the district there is a lively exchange of foodstuffs between various eco-zones. Moreover, Quinuenos have traditionally obtained goods through trade with other areas of Peru, such as coca and chili peppers from the montaña jungles to the east, and wool and hides from Huancavelica, a high-altitude region to the west.

The market, held in the central town each Sunday, is an important mechanism for integrating the exchange between different eco-zones. Most exchanges in the market are by barter—women of different ecological zones exchanging their surplus crops. In addition, a man or woman occasionally may journey to a different eco-zone to trade. The person may, for example, bring potatoes and wool from the higher altitudes to exchange for corn grown in lower altitudes. A few men, in the past, also engaged in long-distance trade by mule train with other areas of Peru. Since the increase in truck transportation during the last 30 years, such organized trade by mule train has disappeared. Today, individuals may take their own produce, usually to Ayacucho or Lima, by truck. However, such exchange is still very small.

CLIMATE AND ECOLOGY

Agriculture in Quinua, as elsewhere in the world, is dependent upon temperature and moisture. In Quinua, these variables are determined largely by seasons of the year and altitude.

Quinua has two major seasons, rainy and dry. The rain begins gradually in September or October, increases in intensity until it reaches its maximum in January and February, then tapers off until it ends around April. The dry season begins in May and lasts until September or October (Rivera, 1967, 1971; Fig. 2). The onset and end of each of the seasons vary from year to year. The amount of rainfall at the beginning of the rainy season differs considerably from one year to the next. It is not until December that the rains consistently come in full force. Distinct dry periods also occur in the middle of the rainy season.

Temperature varies with the seasons (Table 1). The dry season, especially June and July, is the coldest period, with frosts sometimes at night (Rivera, 1967, 1971). The temperature increases gradually in August, so that the rainy season is the warmest

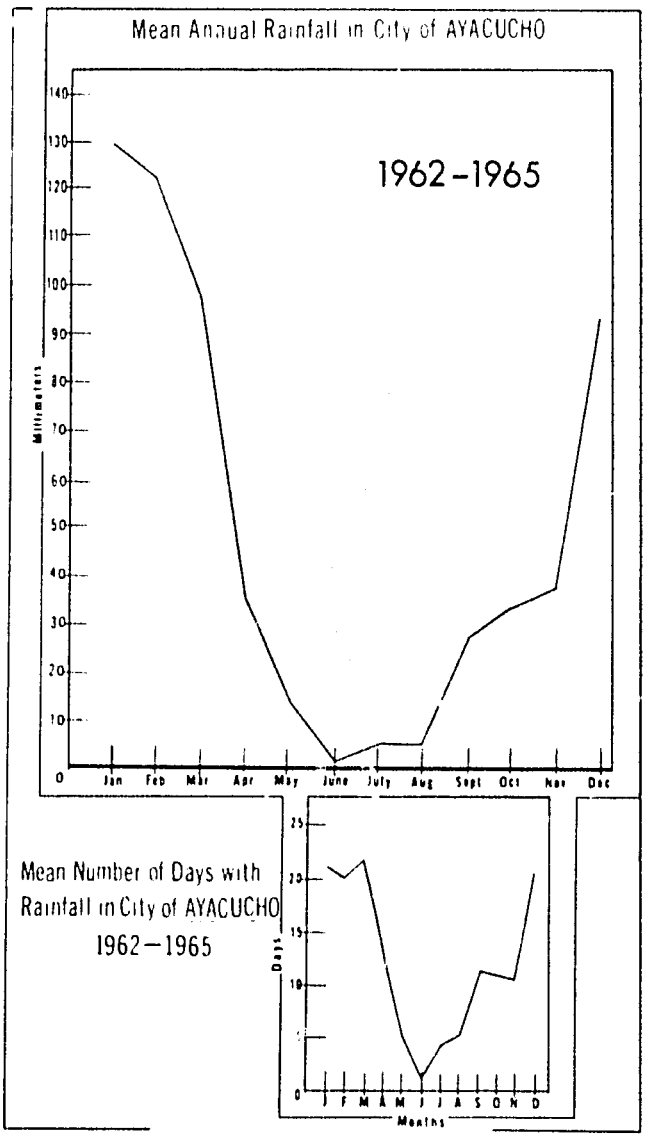

Figure 2. Mean annual rainfall, Ayacucho (data taken from Rivera, 1967).

TABLE 1. Mean temperature in city of Ayacucho, 1962-66 (data from Rivera, 1967)

Month	Avg. Temperature	Absolute Maximum	Absolute Minimum
	Degrees C		
January	15.6	27.0	7.0
February	15.2	25.4	7.0
March	14.6	25.2	6.2
April	14.9	26.3	3.4
May	14.2	25.6	2.2
June	12.4	25.0	−0.2
July	13.0	25.4	−0.5
August	14.1	26.6	1.4
September	15.0	27.1	4.3
October	16.1	27.8	4.6
November	16.6	29.6	4.7
December	16.0	28.0	5.9

time of year. Although the data in Table 1 are for the city of Ayacucho, the situation is similar in Quinua, except that Quinua is at a higher altitude and is therefore colder. It should be noted, however, that diurnal temperature variation is greater than seasonal variation in temperatures (Troll, 1968). In the Andes, frost occurs at night, while daytime temperatures can be quite high. This is true in Quinua and Ayacucho. Consequently, the crucial figures in Table 1 are the absolute minimum (or night time) temperatures.

Moisture and temperature also are affected by altitude. The higher the altitude, the colder the climate. In the Ayacucho region temperature decreases 0.6° C for every 100 m of altitude (Rivera, 1967, 1971). In addition, altitude affects cloud cover and moisture loss. Higher altitudes are cloudier, a frequent phenomenon in mountain environments such as Peru (Bowman, 1916; Hunt and Hunt, 1974; Peattie, 1936). The farther down the mountain slope, the greater the total amount of sunshine. Both sunshine and high temperature cause greater water loss from soil and plants. The terrain becomes drier as one moves down the mountain slope (Arnold, 1975 and Tosi, 1960).

The effects of altitude on temperature, moisture, and sunshine, allow us to delineate six major vertical ecological zones in Quinua (Arnold, 1975; Mitchell, 1976a, 1976b; and Tables 2 and 3). The zones are differentiated not only on the basis of vegetative characteristics, but also on differential human behavior, especially in agriculture and other extractive activities. My discussion of these zones is based on Arnold's (1975) analysis of Tosi's (1960) classification for Peru. The English terms for these zones are derived from Holdridge (1947), which formed the basis of Tosi's work.

The highest ecological zone is the alpine rain tundra/subalpine wet paramo (4 100 + m). This zone, usually characterized as the high puna in Peru, is above the level of agriculture, and is very cold, moist and cloudy. Below it lies the montane prairie (4 000–4 100 m). This area is characterized by ichu grass (*Stipa ichu*) and other frost-resistant, small size vegetation. It is somewhat warmer than the higher zone. Tubers can be grown there even though the area is above the tree line. Still farther down the mountain slope is the moist forest (3 400–4 000 m), characterized by a dense underbrush of small trees and shrubs. It is warmer than higher zones, so that frost-resistant, quick-maturing crops are grown in addition to tubers. The lower montane savannah (2 850–3 400 m) is immediately below the moist forest. The central town is located in the savannah and most of Quinua's population lives here. It is Quinua's major cultivation region, and most of its fields are irrigated. The savannah is divided internally on the basis of irrigation use and altitude into two ecological regions: the upper savannah (3 050–3 400 m) and lower savannah (2 850–3 050 m) (Mitchell, 1976a, 1977). Immediately below the savannah lies the lowest environmental zone in Quinua, the lower montane thorn steppe (2 500–2 850 m). This zone is much warmer, sunnier, and drier than the higher ecological zones. It is covered with cactus and in some areas the vegetative cover may be called a cactus forest. The thorn steppe is unirrigated. It is too dry to be maintained with the very limited irrigation water descending from the savannah. Only plants with low water needs are grown there. In the valley bottom, however, water is obtained from the Rio Chacco. Consequently, this area is irrigated and land use differs here from the upper portion of the thorn steppe. It is for this reason that I treat the valley bottom as a separate environmental zone.

LAND USE

Land use in Quinua is, of course, directly related to the environmental zones. These zones determine broadly whether or not the land is devoted to herding or to cultivation. In a finer perspective, mountain ecology defines such aspects of agriculture as types of crops grown, crop cycles, fallow period, productivity and carrying capacity.

Herding is a specialization of the two highest zones: the alpine rain tundra/sub-alpine wet paramo and the montane prairie. These zones are above the tree line and are characterized by bunch grass and other low, frost-resistant vegetation. Except for tuber cultivation at the lower altitudes in the montane prairie, the growing season is too short for crop cultivation. The people herd pack animals and the Andean cameloids, the llama and alpaca, which are sources of wool and hides. In addition, the people

TABLE 2. Social characteristics of Quinua ecological zones

Ecological Zone	Elevation From	Elevation To	General Characteristics	Land Use	Crop Cycle
Alpine Rain tundra and subalpine wet paramo	4 100 m +		Bunch grass	Grazing	
Montane Prairie	4 000–4 100 m		Bunch grass Frost resistant small size vegetation	Grazing and tuber cultivation	Rainy season cycle
Montane Moist forest	3 400–4 000 m		Dense underbrush of small trees and shrubs	Some herding source of fuel and other wild products Cultivation of tubers and frost resistant, quick maturing crops	Rainy season cycle
Montane Savannah	2 850–3 400 m		Nearly all cultivated	Major cultivation zone Irrigated fields Terracing	Rainy season cycle Dry season cycle
Montane Thorn steppe	2 500–2 850 m		Xerophytic vegetation	Some herding Non-irrigated cultivation of plants with low water needs	Rainy season cycle
Valley bottom	ca. 2 500 m		Xerophytic vegetation	Plentiful water from Rio Chacco Irrigated double cropping Truck farming for City of Ayacucho	Rainy season cycle Dry season cycle

Ecological Zone	Fallow Period	Population Density	Settlement Pattern	Land Tenure
Alpine Rain tundra and subalpine wet paramo		Low	Dispersed	Communal
Montane Prairie	5–6 years	Low	Dispersed	Communal
Montane Moist forest	Long	Low	Dispersed	Communal/Private
Montane Savannah	1/2 year or more	High major population zone	Large nucleated town of Quinua	Private
Montane Thorn steppe	1/2 year	Low	Small nucleated	Hacienda
Valley bottom	None	Low	Small nucleated	Hacienda

of this zone not only herd their own animals, but also care for the animals (e.g., sheep, horses, cattle) of people who live in the upper savannah. Through this intracommunal symbiosis, the residents of the upper savannah are able to maintain more animals than they would be able to otherwise without devoting arable land to forage. When the agricultural cycle begins in August, the people of the upper savannah contract with a herder to send their animals to graze in the higher ecological zones. When the harvest

TABLE 3. Climatic characteristics of Quinua ecological zones (from Arnold, 1976)

Zone	Evapo-transpiration Potential %	Mean Annual Temp. °C	Annual Precip. mm
Alpine rain tundra/ subalpine wet paramo	less than .50	0-6	500-1000
Montane prairie and moist forest	50-1.00	6-12	500-1000
Lower montane savannah	1.00-2.00	12-24	500-1000
Lower montane thorn steppe and valley bottom	2.00-4.00	12-24	250-500

begins in May, the animals are returned to the upper savannah where they eat the gleanings and fertilize the fields. They are used in threshing the grain, transporting produce from field to home and plowing the fields. The fertilizer from animal dung is a very important product as well (Winterhalder (*et. al.*, 1974).

In addition to the high altitude zones, herding is also significant in the driest zone—the montane thorn steppe. Because of low altitude dryness, combined with a very rocky terrain, much of this zone is uncultivated. Consequently, people who live in the lower savannah frequently herd their animals in the uncultivated regions of this zone. A limiting factor on herding here, however, is the lack of water during the dry season. At such times people must pasture their animals near one of the few permanent sources of water.

Cultivation is found in all zones but the highest, the alpine rain tundra/subalpine wet paramo, where the growing season is too short. However, the type of cropping practiced depends very much on the eco-zone. Because of the effects of altitude on temperature, sunshine and moisture, the people in different zones specialize in different crops. In consequence, the type of crop rotation and length of the fallow period varies from zone to zone. Finally, the presence and function of irrigated farming, the type of crop cycle sown, and crop productivity are also zone related.

Quinua has two agricultural cycles: a dry season cycle (the *michka*) and a rainy season cycle (*hatun tarpuy*). Different fields are used for each crop cycle. The dry season cycle is restricted to a small proportion of the fields in the savannah and to the valley bottom. In the savannah, dry season crops are planted early, usually at the beginning of August, and depend on irrigation. Sometimes this early planting is used for double-cropping. Two quick-maturing crops are planted in succession. The second crop, planted around November or December, uses natural rainfall. Generally, however, the land lies fallow between dry season crops. People usually plant a dry season crop not to double crop but to obtain an early harvest when food is scarce. Because of this scarcity, food prices are often very high at this time in the city of Ayacucho, so the dry season crop is often used as a cash crop as well. An additional function of the dry season crop is that it permits two opportunities for agricultural success during the year. It also helps stagger the work load, since the periods of work differ for the dry season and rainy season crop cycles (Mitchell, 1976b). Because there is an inadequate water supply for irrigation for a dry season crop throughout the district, dry season planting is found only in the upper savannah, near the beginning of the irrigation system. In the valley bottom, where irrigation water is plentiful, a dry season planting as part of a regime of double cropping is the rule rather than the exception. Here the dry season planting is always used for double cropping.

The more important, and more widespread, agricultural cycle is the rainy season planting. It produces most of the district's food-stuffs and is present in all the ecological zones that are cultivated. The time of planting, however, differs according to ecological zone (Mitchell, 1976b).

In the montane prairie and moist forest, the two highest zones with agriculture, the rainy season crops are planted in November or December with the onset of the rains. In these zones a limited repertoire of frost-resistant and quick-maturing crops is grown without irrigation (Mitchell, 1976a).

In the lower montane savannah the sequence for planting the rainy season crops depends upon altitude. In the upper portion of the savannah the crops are usually planted over a period of several months. Planting starts in the highest altitudes of the savannah in September and the sequence of planting descends, field by field, until the final fields are planted with the onset of the rains in December. This order is determined by the physical requirements of agriculture in this zone. Farming in the upper portions of the savannah is made possible by irrigation. Irrigated farming is a widespread and ancient Andean method that permits the cultivation of crops—especially maize—at higher altitudes than would be possible with rainfall alone (Mitchell, 1976a, 1977; Murra, 1960). The physical requirements of such agriculture (variables of frost, maturation time of crops, duration of rainy season and amount of irrigation water) demand that higher altitudes be cultivated first (Mitchell, 1976a, 1977).

In the lower montane thorn steppe the time for planting the rainy season cycle is in December with the onset of the rains. In the valley bottom portion of the thorn steppe, however, the rainy season crops are planted whenever the dry season crops are harvested. This is the only area of Quinua in which

there is sufficient irrigation water to permit planting without strict considerations of timing.

The ecological zones not only determine the crop cycle and the time of planting, but also the types of crops grown. Each altitude zone specializes in particular crops. Moreover, the length of fallow period and productivity are also zone related. As a general rule, the higher the altitude the fewer the variety of crops grown, the longer the fallow period, and the less the productivity of the land. The lower productivity of higher altitudes is also a result of the ratio of evapotranspiration to rainfall (Tosi and Voertman, 1964).

In climatic situations in which more moisture is added through precipitation than is lost through evapotranspiration, soluble nutrients are lost from the soil by leaching. This is the case in Quinua in the higher altitudes where the evapotranspiration potential is low (Tosi, 1960; Table 3). In the lower altitudes, however, the amount of evapotranspiration is greater than the amount of precipitation, so that the soluble soil nutrients are not lost as readily from the soil (Tosi, 1960; Tosi and Voertman, 1964). In Quinua, the only areas with a favorable evapotranspiration potential are the savannah, thorn steppe and valley bottom (Table 3).

The highest zone in which crops are grown is the montane prairie. Potatoes (*Solanum* spp.) grow at the highest altitudes and other Andean tubers, maswa (*Tropaeolum tuberosum*), oca (*Oxalis tuberosa*), and olluku (*Ullucus tuberosus*), at somewhat lower altitudes. The fallow period in the zone, especially in potato cultivation, is five to six years. The factors responsible for this long fallow are the limited crop repertoire with which to practice crop rotation and the low evapotranspiration potential, as well as the type of soil and the requirements of the particular crops grown.

A greater variety of crops is grown in the moist forest. In addition to the Andean tubers, this zone is also devoted to other short-growth, frost resistant crops such as wheat (*Triticum durum* and *T. sativum*), haba or broad beans (*Vicia faba*), peas (*Pisum sativum*) and a high-altitude variety of quinoa (*Chenopodium quinoa*).

Much of this zone is uncultivated and the fallow period is several years. Moreover, clouds hover around this zone for longer periods than in other zones. Consequently, much of the zone consists of wild trees, shrubs, and other vegetation. These trees and shrubs are used as sources of firewood and basket-making materials. The wild vegetation is also an important source of culinary and medicinal herbs. The presence of a zone in which fuel is produced helps reduce the reliance on animal dung for fire, and permits the dung to be used for fertilizer, an important Andean resource (Winterhalder *et al.*, 1974). In addition, the presence of a moist forest on the steep slopes above the savannah limits soil erosion and landslides. As the moist forest is located directly above the major population and cultivation zone of Quinua, this is an important, although culturally unrecognized, function of this zone.

The montane savannah is Quinua's major crop production zone, and the zone with the largest percentage of land under cultivation. Irrigation farming (Mitchell, 1976a, 1977) and the cultivation of such staples as maize (*Zea mays*), beans (*Phaseolus vulgaris*), and most squash (*Cucurbita* spp.) is restricted to this area and the valley bottom. Other crops, such as some varieties of potatoes, wheat, barley (*Hordeum* spp.), oats (*Avena sativa*), low-altitude quinoa, and peas are also grown here. The great variety of crops planted in the savannah enables Quinuanos to utilize complex systems of crop rotation and crop interplanting to maintain soil fertility in this zone. Because of such rotation, as well as because of the higher evapotranspiration potential, there is no real fallow period in the savannah. All fields are cropped annually in this zone. In fields devoted to the rainy season planting, the fallow may last only four to six months. In double-cropped fields there is no fallow at all.

The montane thorn steppe, which is farther down the mountain slope, is not as intensively cultivated as the montane savannah. This zone is drier than the upper regions of Quinua. It receives less rainfall, and the evapotranspiration potential is also higher (Table 3). Except for the valley bottom, this zone is not irrigated. It is too dry to be maintained with water from the present irrigation system, so that only plants with low water needs, such as wheat, qewinka (a type of squash, *Cucurbita* sp.), peas, and chick peas (*Cicer arietinum*) are grown. The fallow period is about six months. There are many areas in this zone that are too rocky to be cultivated.

Irrigation water is plentiful in the valley bottom. This makes it possible to plant both the rainy season and dry season crop cycles. Because of the abundance of water and the warm climate, farming in the valley bottom is continuous throughout the year, with one crop planted after another. This region specializes in the production of green vegetables for sale in the city of Ayacucho.

An important aspect of agricultural adaptation to the mountain ecology of Quinua relates to crop specialization. Not only are the species of crops grown different depending upon altitude, but the varieties of the same species are often different as well. For example, three varieties of the Andean grain known as quinoa (*Chenopodium quinoa*) are grown. Each of them is specialized for different altitude zones. Quinoa morocho is a low-altitude variety grown throughout the savannah. Ruyaq quinoa is a variety grown in the upper altitudes of the savannah and the moist forest. Finally, quinoa

morada is sown only in the moist forest. Such variety specialization is true for maize, wheat, potatoes, oats, oca, olluku, maswa, barley, peas, habas, squash, cabbage (*Brassica oleracea*), beans—in fact, most of the cultigens found in the district.

SETTLEMENT AND POPULATION

Productivity and carrying capacity are related to the land use found in each eco-zone. Consequently, settlement patterns and population density also reflect adaptation to the mountain eco-system.

In the moist forest and above, population is sparse and settlements are small. This low population density is a function of the exploitative patterns throughout this region: herding combined with long fallow farming of a restricted range of crops. There is little possibility for intensification here, and the production of calories is limited.

The montane savannah, which is the major cultivation zone, is the region of densest population. Most of the nucleated settlements are located here. The irrigation system, itself an adaptation to the mountain ecology, provides sufficient water for domestic use throughout this zone (Mitchell, 1976a, 1977). In addition, people locate themselves near their primary agricultural fields.

Large settlements are located only in the savannah and only in those areas which permit multiple access to two or more ecological zones. These settlements are located at the border of the montane savannah with another ecological zone. The central town of Quinua and the hamlet centers of Moya and Wiripaqcha are located in the upper montane savannah near the border of the moist forest. This permits ready exploitation of these two zones. In addition, the central town of Quinua is at the physical center of the district, hence it is strategically located as an interconnecting point between all zones and permits people who live near the town to exploit a range of environments. At the market held in Quinua each Sunday, goods from the various environmental zones are exchanged.

Nucleated settlements (viz Liamawillka, Murunkancha, Chiwampampa) are also located in the lower savannah where it borders the montane thorn steppe. People in these settlements live near their major fields, as well as near adequate supplies of domestic water, and utilize the thorn steppe for cultivation of subsidiary crops and to herd their animals. For this reason, people from the lower savannah do not contract to have their animals pastured in the high-altitude ecological zones.

Except for the valley bottom niche, few people live in the montane thorn steppe. Because of the greater evapotranspiration and reduced rainfall there is insufficient water for habitation during the dry season. The few sparsely populated settlements are located near the few permanent supplies of water. The archeological site of Huari, located in this zone, has no permanent habitation at the present time. In the past, Huari probably would have required an aqueduct to provide domestic water for the city (Mitchell, 1976a, 1977). The montane thorn steppe is primarily cultivated at the present time by people who live in adjoining zones.

Although the valley bottom is technically located in the thorn steppe, the abundant and reliable supply of river water permits habitation and, by means of irrigation, extensive cultivation. This zone is more densely populated than the rest of the thorn steppe and contains, as part of the district, two small nucleated hamlets (Chacco and Muyurina). In addition to cultivating the valley bottom, the people from this zone also exploit the upper portions of the thorn steppe.

LAND TENURE

Land tenure also is related to the exigencies of adaptation to the mountain eco-system. There are three systems of land tenure in Quinua: communal, private, and hacienda. Each of these is found in different eco-zones. We will exclude haciendas from consideration because they were imposed through force by the national political system. For private and communal tenure, the most important determining factor is the length of fallow, an observation which has also been made independently for New Guinea (Brown and Podolefsky, 1976). Short fallow cultivation entails major capital investments such as irrigation systems, fences to keep out animals, terraces, and the planting of important perennial plants such as fruit trees, cactus and maguey. Short fallow fields are also more productive. Consequently, these fields are privately owned. Long fallow fields, on the other hand, do not entail many capital expenditures and have large areas of uncultivated terrain, which are used by the community for grazing land, wild herbs, and fuel. In consequence, eco-zones in which long fallow cultivation is practiced are communally owned.

In the moist forest zone and higher, land tenure is communal. The land belongs to the formally recognized rural community (*comunidad campesina*) and technically is distributed by the President of the community. In actual practice, however, this land is inherited by children. However, if land is left idle, ownership reverts to the community which can then redistribute it. Unused land is distributed by the community to those who have passed all their communal civil and religious obligations (*cargos*). A person cannot sell his use rights in communal land.

The real meaning of communal tenure in the higher altitude zones is not that everyone can cultivate here, but that the entire community has the right to utilize

the wild products produced by the long fallow period. People from the montane savannah can thus exploit the terrain for fuel, herbs, and other materials, even though they do not have any cultivation rights. The person with cultivation rights cannot prohibit this use of the land.

In the montane savannah and montane thorn steppe, there is a short fallow and thus fewer wild products. Consequently, most fields in these zones are under constant cultivation, and tenure is private, although in a few areas haciendas own the land. The few important wild plants, such as cactus, belong to the person on whose field they are located. Only the owner of the field has the right to use these plants. Nonetheless, some notion of communal land use is found in these zones. The owner of a field has the first right to graze animals on his field after the harvest. However, once he has done so, grazing rights become communal.

Land tenure is related to ecological zones in another way. The optimal strategy for any family is to have fields in more than one ecological zone. In this way, it achieves maximum diversity in the crops it produces. Such a strategy also minimizes the effects of crop failure which seldom affects all zones simultaneously. In addition, the strategy of different fields in different eco-zones allows a person to sow his fields in succession, thus staggering the workload. Few people, however, are actually able to achieve this optimal tenure strategy.

SOCIAL ORGANIZATION

Other dimensions of social organization related to the vertical ecology are the system of social stratification and barrio organization. A common phenomenon throughout Peru is the belief that Indians are found only in high altitudes. In Quinua, the people of the savannah and lower elevations tend to regard everyone from the high altitudes as *a chutu* or Indian, which is a mark of disrespect (c.f. Mitchell 1974). Nonetheless, most people speak Quechua and are racially similar, regardless of altitude. Consequently, the different perceptions are at least partially linked to differential productivity. Indians are those who exploit terrains of low productivity. This low status of *puna* inhabitants may go back to pre-Columbian times as well (Garcilaso de la Vega, 1966).

The *barrio* division of Quinua is another aspect of social organization related to the vertical ecology. Since some aspects of the fiesta system and political organization are organized around barrio lines, these social features are at least indirectly related to the mountain ecology as well.

Quinua is organized into two barrios: Lurin Sayoc and Hanan Sayoc. This division is very important in the political, religious and ecological organization of the community. Each barrio has its own irrigation system. They also alternate in giving annual religious fiestas. In the recent past each barrio also had a separate rural political organization (*varayoc*). These barrios are not moieties, a term which should be restricted to dual kinship divisions (Murdock, 1949). Membership and participation in the barrio is determined by residence; it is not based on rules of descent. Moreover, the barrios are not upper and lower altitudinal divisions as is frequently assumed to be the case in other parts of the Andes. Barrio divisions are very ancient in Peru, going back to Inca and probably pre-Inca times (Baudin, 1961; Castro Pozo, 1946; Garcilaso de la Vega, 1966; Kirchoff, 1949; Means, 1931; Montesinos, 1920; Rowe, 1946). They are found widely in the highlands today, although the division is sometimes into three or four rather than two units (Adams, 1959; Arguedas, 1964; Isbell, 1972; Mishkin, 1946; Snyder, 1960; Stein, 1961; Tschopik, 1946 and 1951).

Quinua's barrio divisions are based on the hydrology of the mountain slope on which the community is located (Mitchell, 1976a, 1977). The central area of Quinua lies on a mountain slope with two major drainage systems (Fig. 3), one draining into Huamangura ravine, and the other into Hatun Wayqu (big ravine). The dual division of Quinua into Lurin Sayoc barrio and Hanan Sayoc barrio reflects this hydrological situation, and the ecological and cultural boundaries coincide. The hydrological basis for the barrio division is not verbally recognized by the community and it may be for this reason that it has not been reported elsewhere in Peru, although the literature suggests that the pattern occurs elsewhere (Mitchell, 1976a, 1977).

The major productive variable in the hydrological basis for barrio organization is irrigation technology. The irrigation systems of Quinua exploit the drainage patterns on the mountain slope. Consequently, there are two separate irrigation systems, one for the barrio of Lurin Sayoc and another for Hanan Sayoc. Since irrigation is itself an adaptation to the vertical ecology, in that it raises the upper limit of maize cultivation (Mitchell, 1976a, Murra, 1960), barrio organization is indirectly related to the mountain ecology as well.

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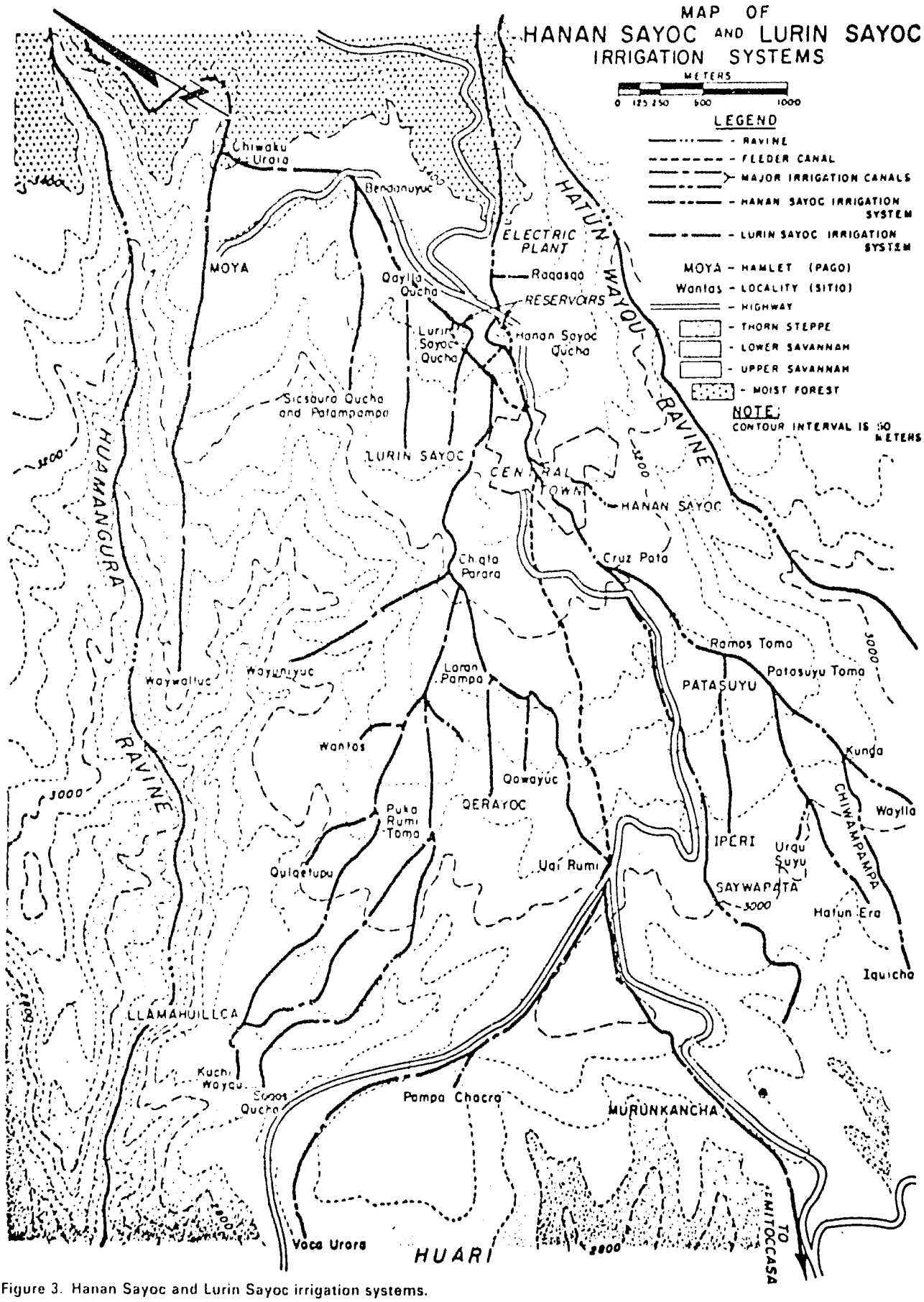

Figure 3. Hanan Sayoc and Lurin Sayoc irrigation systems.

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34.
Socio-Ecological Evolution in the Hill Country of Southwestern West Virginia

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Hill lands throughout the world possess certain characteristics: (1) they are poor in economic terms; (2) they are often overpopulated in relation to the resource capability of the land; (3) their lands are marginal and can seldom sustain the degree of cropping, timber harvest, and grazing that is customary on flatter lands; (4) their population is often isolated from the main stream of life in the country; (5) when their environment starts to deteriorate on steep slopes it deteriorates more quickly than on more gentle slopes and plains; (6) once deterioration sets in the damage is more likely to be irreversible, resulting also in irreversible economic conditions; (7) degenerating ecological and economic conditions push waves of immigrants out of the region into lowlands and urban areas; and (8) ecological changes that take place in hill lands force changes in the lowlands.

A typical example of hill country is that part of Appalachia embraced by southwestern West Virginia, eastern Kentucky and western Tennessee. I will place emphasis on southwestern West Virginia. There interactions between man and the environment have resulted in a steady deterioration of hill land ecosystems, and in turn the hill environment has molded the ecology of human populations.

The Appalachian hill country is a peneplain strongly dissected by a dendritic drainage pattern. The elevation ranges from 180 m in the extremely narrow valleys to 820 m along the narrow ridgetops. The hills, with slopes of up to 85%, rise abruptly from the narrow stream bottoms and the ridges drop off sharply. Ecologically, Appalachia is a forested region containing one of the greatest diversities of plant species in North America. This diversity reflects a wide variety of microhabitats and site conditions created by slope, aspect and drainage patterns.

The ecological conditions, human and otherwise, that exist in this region today were determined by the ecological conditions of the Paleozoic. For 400 million years of the Paleozoic era the area that became Appalachia was swamp land supporting dense luxurious forests of high tree ferns, seed ferns and Cordaniles. These swamp forests were buried under accumulating sediment washing in on a subsiding land. The masses of sedimentary rock that eventually formed were pressed into folds and thrust upward through the Paleozoic formations into great mountain chains. Erosion wore the peaks down into rounded hills and reduced the cover over coal beds, exposing them in places.

This Appalachian hill country has a long history of human occupancy around its periphery. The earliest known inhabitants were the Paleo-Indians who entered the Kanawha and Ohio River valleys at least 14 000 years ago and were followed by a series of other Indian cultures (McMichaels, 1968). The Indians hunted, fished, gathered wild fruits,

seeds and plants, and practiced a simple form of agriculture. The hills, however, were penetrated only by Indian war paths, used in the last years of Indian occupancy during the early 1700's by war parties of the Iroquois Confederacy whose untended camp fires caused periodic fires that swept the region. The end of Indian dominance of the region in the late 1700's opened up the Appalachians for safe travel and settlement. As early as the mid 1700's population density of white settlers built up on the periphery (Speed, 1886). In 1763 Daniel Boone laid out the Wilderness Road through a gap in the Cumberland Mountains, discovered in 1750 by Thomas Walker. This road, little more than a trace, carried thousands of pioneers to the fertile lands of western Kentucky. Another more dangerous route was the Ohio River. These two major travel routes skirted the interior mountains, which were regarded by many immigrants as undesirable places to settle (Imlay, 1797).

In spite of this, settlers, nearly all veterans of the Revolutionary War, came to claim grants of land offered them in place of money for their services as scouts, fur traders and Indian fighters (Rice, 1970). Attracted to the hills by an abundance of game, their own familiarity with the region, and the opportunity to escape advancing civilization, the settlers lived mostly by subsistence hunting that provided both food and clothing, growing only what additional food they might need (Rice, 1970). With simple agriculture as an energy base, the hill people were able to devote an excessive amount of energy and time to hunting game even when it became scarce. By 1850 the game population of the hills had virtually disappeared forcing the people to expand subsistence agriculture, the second developmental stage in the region.

By 1850, too, immigration into the region ceased until the early 1900's. Up until that time a continuing influx of settlers, largely Scotch-Irish, settled in the narrow valley bottoms (Campbell, 1921). Many stayed close to the branching arteries of traffic that led down the Ohio and up the Kanawha, Little Kanawha, Big Sandy and the Guyandotte. The increasing availability of lands to the west and south of the region and the rapid improvement of roads on the periphery of the hill country drained all traffic from the interior. Those who settled on the formerly traveled roads found themselves isolated along with those settlers who sought isolation from society in the remote coves and hollows.

A rapidly growing population and a barter economy was supported by patch or swidden argiculture (Smith, 1916). The highlanders were not agriculturally inclined. They knew little about growing crops. They cleared the land by burning or deadening the timber. In the cleared land about the stumps and deadened trees they planted corn, the staple crop squash, beans, potatoes, turnips, flax, tobacco, and later sorghum.

A common rotation on larger farms was corn for one or two years, then grain for another year, followed by a year or two in hay. Next, this land was pastured by a few cows and horses until the grass was gone and broomsedge and weeds claimed the ground or erosion carried off the top soil. Steepness of the land was no deterrent to the highlander. It didn't take many rains to send the topsoil and stones roiling down the hills into narrow valleys. As quickly as one hillside was worn out, the highlander cut down more forest for new fields. As the land wore out and the population increased, the highlander was forced to open more and more land in complete disregard of continued depletion of soil.

The destructive practices in agriculture extended to the surrounding land. The highlander had little regard for the forest. To him it was at once an enemy and a friend. He had to clear a part of it to establish his homesite and his hillside fields and he burned it frequently to open it up for forage for his cattle and hogs. Yet at the same time the forest provided a sense of isolation, a measure of security, a source of game and medicinal herbs, fuel and wood for tools and buildings. The fact that the forest was rich in the finest timber species and might bring considerable economic return never really occurred to him; or if it did, he chose to ignore it (Campbell, 1921).

The hills in turn shaped a cultural development and imposed restraint on social and economic development. The people moved into what was essentially an island situation. Hemmed in by topography and living in extremely marginal agricultural land, the people were isolated from other human populations, an isolation further intensified by a lack of communication and movement to the outside world. This geographical isolation imposed upon the people conditions quite comparable to the situation of any organism isolated from other populations of its own kind. Gene flow is often restricted, little new genetic material is introduced into the population, and considerable inbreeding takes place. The behavioral and cultural traits were reinforced by isolation imposed by the environment and the peoples' own rejection of the outside world (Weller, 1966).

One trait upon which isolation had a pronounced influence was independence—a person's distaste of being told what to do, unwillingness to bend to the rule of the majority, dislike of working together and mistrust of any group or individual that tries to impose someone's will on him.

Out of independence evolved territorialism, individualism and person orientation. Territorialism resulted when one hollow or series of connecting hollows became the domain of a kin group. Once settled each hollow was rather effectively sealed from

the others with boundaries usually marked by the ridge tops. Usually there was little contact between occupants of one hollow and those over the ridge. Such territoriality resulted in limited communications, limited group activity, interfered with courtship patterns, and in many ways enforced inbreeding.

Individualism involves independence from social constraints and absenteeism from cooperative efforts. The highlander's approach toward society, government, or any activity has as its basic motivation his own well-being and his own basic concerns (Gazaway, 1969). This self-orientation leads to the third trait, person-orientation. What motivates the hill resident is the goal to be liked, to be accepted, to be a part of a small group rather than to achieve money or material success.

Another trait common to all hill cultures is traditionalism, the ideas that the ways of the past are the best ways for today and there is no looking forward to tomorrow. Along with traditionalism goes fatalism. When the settlers moved to the mountains they had aspirations for the future, but they achieved little, mostly because the hill land could not be made to produce for man. With population pressures rising, with increasing demand for land that was never capable of supporting much of a subsistence agriculture, the mountaineer found his confidence undermined. To excuse his failure he adopted a fatalistic attitude. This passive, repressed attitude is passed on to the children and serves as a buffer against disappointments to them as well as to adults (Cole, 1971; Gazaway, 1969).

Finally there is kin orientation, the center of which is the family. This results from an emotional dependence people have on one another, rather than any deep, cooperative interest in each other. The family is male-dominated, adult-oriented, with children receiving little in the way of adult guidance. Outside of the kin group the mountaineer is relatively uncommunicative.

While the hills had an impact on the social and cultural development of the hill people, the subsistence agriculturalist also had a pronounced impact on natural ecosystems. The settlers occupied a mature and relatively stable ecosystem, but they began a rapid disruption of normal ecological processes by the wasteful burning of forest, soil erosion and over exploitation of wildlife. By the 1880's the natural ecosystem had been so degraded and the human population had risen to a point where it was hardly able to sustain itself on subsistence agriculture.

At this point a new human successional stage in the hills emerged, the timber period. In the late 1880's rich timber stands of the mountains were discovered by the eastern lumber industry. This was the first real penetration into the region by the outside world. Eastern corporations established for the purpose of buying timber and speculating in hill land moved into the region. Unfamiliar with either ways of money or how to negotiate sales, the highlanders sold their timber at give-away prices. Eastern lumbermen also discovered that highlanders were holding land for which they had no legal title, and sent in surveyors to claim land that had not been formally patented. Often the surveys took in land both legally and illegally claimed by highlanders. The few cases that went to court were usually settled in favor of the lumber industry. As a result, many highlanders lost the land they thought they had (Caudill, 1963).

In many parts of the hills the people looked with considerable favor on the coming of the timber industry (Bowman, 1965). For those living on worn-out or over-populated land, the sale of timberland and trees benefitted them. The lumber industry provided just enough jobs and money in the region to hold families together on otherwise unproductive lands for another generation.

The timber industry hastened the ecological deterioration of the region. The income kept the mountaineer on the eroded land. Logging was wasteful and was usually followed by fires. The burning consumed forest litter, reduced organic matter accumulation, killed tree seedlings, affected botanical composition of the forest stand and increased erosion of the slopes. The continuing patch farming, the increasing population pressures on the region, the destruction of the forest ecosystem intensified the steady deterioration of the mountain environment.

Coal mining followed timber harvesting. When railroads penetrated the hills to bring out timber, they also opened up the region for exploitation of coal. The reports of an abundance of coal and the poor legal claims of the mountaineers to the land prompted speculators to send their agents into the field to buy up land. The end result was a new and greater influx of eastern and foreign capital to the coal fields and an end to local ownership of lands and minerals. Today 75% of the land is in corporate ownership (Miller, 1974).

Because of his nature, the highlander was an undependable source of local labor, so the coal industry brought in coal miners from outside the region (Thomas, 1972). It tapped two sources for labor, the black workers of the deep South and immigrants from foreign lands, mostly the latter. These people were aliens to the mountaineer, with different values and a different way of life. The immigrant workers were sheltered in towns constructed by the coal companies. The houses and businesses were owned, controlled and operated by the companies, which also provided all community services from voting to burial. Thus, the companies imposed urban or village settlements in regions, brought law and courts where none existed before and concentrated masses of people in narrow valleys.

The result was a cultural shock and a sudden increase in population in a region that basically was already overpopulated. Overcrowding was a problem and sanitation conditions were extremely poor. In early days of coal exploitation, epidemics of smallpox and other diseases were not uncommon (Thomas, 1972). Subsistence agriculture was replaced by a cash economy and the region shifted from land-based economy to one supported by an exploitative industry.

Under these conditions environmental degradation continued at an accelerated pace. The slopes were stripped of trees for mine props, railroad ties and lumber. Fires, often set by embittered native populations, were frequent. Mining and coal preparation operations polluted the air with particulate matter and sulfur dioxide. Inversion, common in deep narrow valleys, held in the smoke and pollutants for days. Water pollution from sewage, coal washing, soil sediments, and mine acid drainage destroyed aquatic life and turned clear streams to black and yellow. The effects of such pollution were even felt hundreds of miles downstream and outside the region.

Deep mining of coal was followed by an even more environmentally damaging practice—surface mining. Although this method of mining coal was used in the mountain country as far back as 1870, it did not become extensive until the 1960s, and has since accelerated. Because of the hilly and steep terrain, the most common method of surface mining is contour strip mining in which the coal is removed from benches on the slope and the overburden is cast downslope. Although reclamation techniques have improved, it is difficult to restore such areas, and it is virtually impossible to correct the damage suffered by mountain ecosystems (Smith, 1973). The forest cover on the disturbed areas is completely destroyed; the instability of the overburden results in enormous erosion problems. Silt fills stream bottoms. This increases the intensity of floods. The mining destroys the forest ecosystem and adversely affects the area for future forest growth, and in most respects the region is left unattractive and unsuited for continued habitation. Reclamation depends largely on grass, the growth of which is most successful on bench and upper one-third of the slope. It is doubtful whether the disturbed lands will ever undergo normal vegetation succession even in several lifetimes.

The mountaineer through his long tenure in the mountains has been able to exist with and even ignore, if not condone, such environmental abuses as destructive logging and annual fires. He simply has accepted the pollution of streams from mine acid discharges and siltation from coal washeries. But his attitude toward strip mining is one of frustration and anger. The reason is that in the southern Appalachians the people relate to a particular location. They identify themselves with a particular locale, a specific and familiar ridge, a particular hollow or stream. The mountain resident associates time and place together including the human relationships associated with them. It is the violence that surface mining does to this relationship that not even the most careful reclamation can restore (Randall, *et al.*, 1976).

The environmental deterioration of the hill country is reflected in the logistic growth curve of the population. By the 1850's the population had reached the carrying capacity that the region could support by agriculture. Some emigration took place but it was slowed by the coming of the timber industry and did little to reduce population. In the 1900's the population grew rapidly due to the influx of workers into the coal fields and a high fertility rate (in 1930 it was 651 per 1 000 women aged 15 to 45; in 1970 the fertility rate was 522). In the 1950's the population growth was abruptly halted and began to decline. Because of a declining market for coal and increased mechanization of the coal industry, jobs became scarce and there was a great movement of people out of the region over the next two decades.

The hill country of southwestern West Virginia and its associated hill lands of eastern Kentucky have gone through five developmental stages, each with its own cultural, ecological and demographic characteristics.

1. Subsistence hunting that supported a small human population and depleted the region of its game.

2. Patch or swidden agriculture that supported a rapidly growing population and a barter economy, depleted lowland soils and forced more and more of the population onto the steep hillsides and into remote hollows.

3. Timber harvesting. This involved the invasion of the region by the eastern financial establishment, provided part-time employment, introduced a cash economy, halted emigration out of the region, depleted timber resources, and resulted in the beginning of the loss of control of the lands by the native population.

4. The coal mining stage. This brought in railroads, settlements, laws and courts, immigrants, replaced barter and agriculture with a cash economy, imposed a foreign social culture onto a traditional mountain culture, stimulated a logistic population growth, forced the passing of land from individual to large corporate ownership, and caused a rapid ecological deterioration of the region.

5. Surface mining stage. This has destroyed the ecosystems as they have existed.

One can only guess about the future of these hill lands. The marked decline in the population has been halted temporarily because of the resurgence of the coal industry. But what will come after the last of the coal has been removed? Surface mining will leave eroded land, silt-filled streams and torn-down mountain slopes that will be unable to support the rich forest growth that once covered them. As the region deteriorates, the hill people will be forced from their homes. The long-term future of the region, ecologically, economically and culturally, looks bleak.

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DISCUSSION

Unidentified. When will this abandonment take place?

Smith. A long time in the future. At present there's an influx of coal technologists, but as the coal is depleted, these people will leave. In perhaps 50 years McDowell County will be abandoned.

Some miners feel that only the coal that is easiest to obtain is being removed and what's left will be very difficult to mine. It's a shortsighted policy.

Unidentified. How did the outside interests get control of the land?

Smith. John William's recent book, West Virginia and the Captains of Industry, describes the ways in which the Eastern timber and coal barons got control of the resources. There was no consideration of the long-run interests of West Virginians. Three quarters of the land down there is owned by coal companies.

Who's going to live in these areas? There's little or no timber production potential. I see little hope for the region.

C. Evans (Colorado, USA). What is the potential for forage-based livestock production?

Smith. There is such a potential in the northern areas, but slopes are too steep in the five-county area I'm talking about. I'm not sure the coal companies are interested in it. The area was only one of patch agriculture before the mining occurred—it's not really an agricultural area.

35.
Past and Present in the Swiss Alps

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Hill lands have traditionally been marginal because problems of low productivity, isolation, and transportation made their exploitation impractical and unprofitable for anything other than subsistence farming. Improved agricultural techniques and mechanization increased yields in lowlands. Faced with growing discrepancy between mountain and plain production, the response of many hill farmers has been to abandon their unrewarding farms for what they believed would be better paying jobs in another profession. Switzerland has experienced these tendencies but there have been attempts to counteract them through explicit government policies to favor mountain agriculture. However, at the same time that officials recognize the need to maintain and encourage farming in marginal areas of Switzerland, they expect that tradition will give way to new methods and organization. To adapt old structures to new exigencies, it is necessary to understand the origins of the system, its evolution and function. The historical perspective provides this insight. Thus, I will first discuss the politico-historical context of Switzerland which favored the development of decentralized institutions, and I will then analyze the institutions themselves. The government must now interact with these structures; its goals and policies will be outlined. Finally, I will evaluate the efforts to implement these programs, assessing their positive and negative aspects.

THE GEOGRAPHIC SETTING

Specific data about local level organization has been collected from a small mountain community in the canton of the Valais, Praz-Fleuri (canton is an administrative unit which corresponds to an American state). Though each Swiss village is unique in some respects, the data I have from one can be used to illustrate general problems of Alpine agriculture. The Valais is dominated by the Rhone River with its flood plain and the mountain chains rising steeply above it. Deep lateral valleys cut into the mountains. Villages are located in the plain and in the side valleys. The agricultural systems of these are totally different. In the river flood plain, a market-oriented agriculture emphasizing fruit, vegetables, and wine has developed. In the higher altitudes one finds a pattern of mixed subsistence farming that makes use of the steep, terraced slopes for fields, pasture and meadow. The constraints imposed by the rugged terrain and climate, isolation and problems of transportation and communication have shaped economic activities and led to institutional arrangements which clearly distinguish Alpine peasants from those in the plains.

THE HISTORICAL CONTEXT

The physical environment was not alone in influencing the development of particular structures. Villages also have always been part of a political environment characterized by a specific relationship between peasantry and state. The history of the formation of the Swiss state is of special interest because the impetus for its organization came from the local level rather than being imposed by an outside, centralizing force (Deutsch and Weilenmann, unpublished MS). The political consolidation of the Swiss cantons and of Switzerland as a nation followed a similar pattern. While acknowledging important local variations, I will discuss this evolution from the perspective of the Valais because the focus here is upon a single Valaisan village as it developed from an economic to a political unit.

The process of state building originated and took shape during the feudal period, beginning in 999 when the Valais came under the control of the Bishop of Sion. This official delegation of political control, to be added to the bishop's religious sovereignty, was no guarantee of real power. It heralded a centuries-long struggle which was fought on two major fronts. Noble families competed first among themselves and then against the bishop to enlarge their holdings. And the rural masses continually sought to free themselves from feudal lords, noble or ecclesiastic, in order to preserve and extend their autonomy.

These conflicts led to an alliance between the bishop and rural communities against the nobles. Peasants exchanged their military support of the bishop for political freedoms. In 1475 the most powerful noble lords were defeated by this peasant-bishop coalition. Their victory consolidated peasant powers; communities were left free to make decisions about local issues. Policies concerning the Valais as a whole were elaborated by a popularly elected assembly.

Rural communities throughout Switzerland followed the same trends: a strong free peasantry with some economic autonomy sought to preserve these

privileges from domination by noble expansionist efforts. Rural alliances later joined with urban bourgeois trading interests, also threatened from the top. In the period from 1400 to 1800, two opposing tendencies struggled for supremacy. On the one hand, each commune,[1] and later canton, sought to preserve the greatest possible independence. On the other hand, they were willing to ally to strengthen their autonomy from incursions from above. Total community autonomy was never an option; small units would have quickly been absorbed by the centralizing efforts of noble leaders. Rather, peasants and urban bourgeois united to resist centralization. By forming a confederation of sovereign states, the Swiss created a nation built upon horizontal coalitions. The result of these alliances made among people equally anxious to preserve their particularities, was a decentralized state that had a central federal structure but left great freedom to canton and commune.

Thus, within this context of state building, rural settlements evolved into communities. By the early feudal period, the subsistence patterns had been established. Cattle and grain production were the most important elements of this largely self-sufficient system. Fields and pastures were scattered above and below the settlement. Crop land was farmed by individual households; meadows and some pastures were also divided into private holdings. The summer pastures were managed communally, protecting them from individual domination. Water and forests were also under collective control.

Feudal lords spent little time in their isolated fields so local inhabitants were free to administer certain activities. Community assemblies set economic policy and, as tasks grew in complexity, administrators were elected. Economic autonomy at the local level combined with increasing political control wrested from the bishop resulted in economically and politically viable communities.

Given this development, it is valid to choose the village as one primary level of analysis. Local institutions regulate village life and are relatively free of influence from other levels of government.

ORGANIZATION OF RESOURCES

The agropastoralism which sustains Valaisan Alpine peasants has a characteristic pattern of land use. Its essential features are its vertical perspective, the mixture of private and communal holdings and the division of cultivable land into small plots.

[1] Smallest administrative unit, corresponding roughly to an American township. However, in Switzerland it has maintained a great deal of autonomy. Swiss citizenship depends upon membership in a commune and certain rights and privileges result from it.

Commune territory in Praz-Fleuri emcompasses land between 655 and 2842 meters. The southwesterly exposure allows agriculture between 950 and 2100 m. Different agricultural tasks are associated with each level.

Praz-Fleuri is a nucleated settlement located at 1350 m. People live in clustered wooden chalets interspersed with buildings used for grain and hay storage, as stables or as potato, wine and cheese cellars. In and around the village are the meadows, grain and potato fields and kitchen gardens. Between 1500 and 1700 m are the mayens, individually owned pastures. High above the village, at about 2100 m, are the two alpages. These are collective pastures, managed in Praz-Fleuri by users' cooperatives. Villagers also own vineyards in the Rhone River Valley.

Alpine cattle utilize a wide range of altitudes. Through the year, they move from the village, through the mayen to the alp and back again. This cycle largely determines the rest of Alpine peasants' activities. In early spring the cattle are brought out of the stables where they have fed on hay during the winter. They graze near the village. Peasants prepare fields for planting and tend their vineyards. In May the cows and their owners move to the mayen where each family has a small hut. Here small cheeses are made from the spring milk. When the cows are taken to the high alp at the end of June, they are cared for by hired labor, leaving their owners free to devote all their time to the haying and harvesting of crops. The cows are brought down from the alp at the end of September. The cattle spend a few more weeks in the mayen, then in pastures around the village, and they are again shut in their stables for the winter.

Alpine mixed farming based on animal husbandry and grains supplemented by potatoes and garden vegetables permits a high degree of village and household self-sufficiency. It is dependent on the availability of all land types to each household.

The basic unit of production and consumption is the domestic group. Decisions about private resources are made by the head of the household within limits set by the community. Under domestic control are houses, stables, hay barns, fields, meadows and some pasture land. Influenced by the ecological constraints, the needs of the family as it evolves determine which fields are to be planted, what crops are to be grown, how the division is made between garden, field, meadow and pasture (Wiegandt, 1976).

However, village rules impinge upon individual liberties. Collective duties place limits on individualism while favoring the well-being of the group as a whole. At the same time, individual use of communal resources permits the survival of discreet household units.

Under communal control in Praz-Fleuri are the Alpine pastures, irrigation canals and forests. Upkeep is assured by users; administration and record-keeping are carried out by rotating part-time officials.

These institutions provide a viable environment for community members. Communal lands preclude the development of a landless class and help to equalize access to resources. Their organization assures that members are also decision-makers, administrators and laborers. Within these institutions, land is owned in common and power positions are shared. A certain egalitarianism is further preserved because no one association contains exactly the same members as any other. Only with difficulty can an individual develop a power base because he doesn't control all the crucial institutions. Crosscutting allegiances also tend to inhibit the polarization of the village into opposing groups. If such a split nevertheless occurs, this same network of relationships acts as a reintegrative force (Wiegandt, 1976).

THE INHERITANCE SYSTEM

The control and distribution of common lands is assured by the various corporate groups. The mechanism providing for transmission of private holdings from generation to generation is the system of inheritance. In Praz-Fleuri, and the Valais in general, partibility has prevailed since feudal times and is consistent with current Swiss law. The characteristics of the system are also in part determined by the natural and social environment.

Mixed farming as a subsistence strategy dictates the need for different land types. The size and dispersal of plots however, results not from the nature of the exploitation but rather from the physical characteristics of the land. Small scattered fields are a result of the inheritance process: in each generation the family holdings are divided among surviving children. This fragmentation, if kept within bounds, is appropriate to the Alpine environment. In the mountains there are mini-ecological zones; changes in land quality and differential exposure to sun and rain occur abruptly and within small distances. An estate made up of many small parcels located at different altitudes and facing in different directions is less vulnerable to losses due to such changes.

Inheritance practices also have a social dimension. Life choices are influenced by the extent to which a person is assured of part of the family estate. The size of this share is a factor in determining his social and political status within the village.

Allocation of resources through inheritance also shapes the social structure of the village as a whole. Viewed historically, inheritance practices elucidate the process by which wealth moves through the community. In each generation, estates are broken apart. Because women inherit equally with men, a new estate is formed with each marriage.

An individual's wealth is determined by: his parents' fortune, the number of his siblings, whether or not he marries and the size of his spouse's holdings. By evaluating the hierarchical relations among families through time, the role of inheritance as a factor leading to a certain equilibrium can be established.

I have shown elsewhere that there is a correlation between family size and wealth (Wiegandt, 1976). Wealthy families tend to have more children than poor families, which means that, because of partible inheritance, large holdings are divided into proportionally more parts than small ones. A statistical analysis shows that the results of this process is the equalization of economic status over time. The percent of total village wealth was calculated from the tax rolls for several generations of men. In general, there was downward mobility because population increased. But the drop in relative wealth was greater for sons of wealthy fathers than for sons of poor farmers. The percentage of decrease was correlated with father's fortune. The estimated regression equation is:

$$y = 0.67x - 0.55$$

The correlation coefficient was calculated and yields the result:

$$r = 0.82$$

From this, I concluded that inheritance practices played a significant role in preventing a growing discrepancy between rich and poor.

This brief analysis has presented a Swiss Alpine village as a system in which communal economic institutions and inheritance practices interact to maintain a relative egalitarianism within the population. Relationships are not static. The system must be viewed as a dynamic interaction among the constituent parts.

GOVERNMENT IN AGRICULTURE: THE GOALS

Although Switzerland is a decentralized state in which canton and commune jealously guard their freedoms, there has been a realization that a coherent national policy must be created to face the challenges of rapid communication, industrialization and interdependence. The need for high-level coordination of the agricultural sector was acutely felt during World War II when Switzerland feared she would be cut off from her food supply. Thus, one of the important motivations of Swiss planners is strategic: the nation should be able to provide food for itself in an import crisis. This implies the maintenance of reserves. It also means that lands which are not usually profitable must be ready for production when needed.

A second consideration of the government is to preserve an ecological equilibrium. Officials are concerned with keeping a balance between forest and open spaces as part of their policy to encourage tourism, a crucial national industry. They appreciate the esthetic value of the contrast between forest and meadow. The survival of mountain agriculture is necessary to keep the diversity of the Swiss Alpine landscape. The open spaces must be cultivated to discourage erosion and prevent fires.

The people of Switzerland support government aid to agriculture for a third reason. Many former agriculturalists keep their land because they feel it is insurance against possible economic crisis. This attitude provides support for government attempts to maintain agriculture in areas where short-term economic considerations alone cannot be the prime motivation.

GOVERNMENT IN AGRICULTURE: THE POLICIES

The federal government works to realize three goals through a series of laws, some of which apply particularly to mountain agriculture. These measures fall into four basic categories: market and price controls, subsidies, improving agricultural efficiency and credit and investment.

The rationale behind Swiss price policies is to assure agriculturalists a revenue equivalent to that available in comparable positions in industry. In most of Switzerland agriculture remains small scale and family-based because much of the environment precludes an industrial agriculture, so policies are protective. Imports are limited either through the imposition of duties or quotas. The border is closed altogether to foreign fruits and vegetables during the period when Swiss products can fill domestic demand.

Price controls also assure a certain standard of living for producers. The milk industry is the principal source of Swiss agricultural revenues, providing one third of the value of agricultural production. The Swiss Federal Council (the executive branch) periodically fixes the base price of milk guaranteed to the producer. The price of cereals is also fixed by the federal government which buys all the indigenous production.

Animal husbandry, traditionally the basis of Alpine subsistence, received special support. Fixed prices are paid to meat producers. In addition, mountain peasants receive subsidies for keeping animals. The higher the altitude, the larger the subsidy. There are also federal contributions to the cost of transporting animals in mountain regions.

Encouragement is given to improvements in agricultural techniques. Federal and cantonal schools and experimental farms provide for teaching and research. Efforts are made to improve crop varieties and the quality of meat and milk producing animals. The latter policies are of particular concern to mountain cultivators. They obtain subsidies for destroying inferior animals. Peasants also receive contributions enabling them to buy forage and fertilizer.

There is also a movement to create estates of continuous fields. This implies a movement away from the traditional pattern of small scattered holdings.

The fourth method of aiding agriculture is to make credit easily available to farmers. Cultivators are eligible for very low interest or even interest-free loans to finance improvements. Investment credits are obtainable by individuals or communities.

These measures show that Swiss policy makers have established a range of programs to provide aid to agriculture. The needs of each region and product are taken into account. The result is a disparate collection of laws integrated by the goals underlying them rather than by the specific, often contradictory, effects they have on production.

THE IMPLICATIONS FOR A MOUNTAIN COMMUNITY

It is evident that government intervention in production alters the traditional structures in Praz-Fleuri which, like other Valaisan villages, existed so long with only marginal connections to the world beyond it. At the same time, it must be acknowledged that the village had begun to change significantly before the federal government became involved in directing the course of agricultural development. Until the late nineteenth century, residents of Praz-Fleuri lived mostly from subsistence agriculture. Tax records show that people had almost no cash income (Wiegandt, 1976). As the Valais began to develop and industrialize, employment became available to mountain people. Beginning in the 1930s, several hydroelectric dams were built and there was a sudden demand for workers. Many peasants left to seek jobs which would bring them more money. Improved transportation drew these isolated mountain villages into the modern world—a world that functioned with money they did not have. The movement from agriculture continued to the extent that officials spoke of a "crisis of mountain agriculture." The federal census shows that population of Praz-Fleuri dropped from 385 in 1920 to 249 in 1970. The response of the government has been to provide incentives for mountain people to remain in their villages and to continue with at least part-time agriculture. The policies they have elaborated must be assessed in the light of the changes that were occurring. Some government actions may hasten the breakdown of traditional structures, but they have not instituted it. Nevertheless, government programs give a certain direction to the evolution of Praz-Fleuri and can be analyzed in terms of their impact and the reactions of the people to them.

The ecological balance may be altered by the introduction of new crops. It is impossible to adapt the traditional economy based on cattle raising and grains to the exigencies of the market. The extra costs and lower yields of mountain agriculture make it a poor competitor with more mechanized plains cultivation. There have been attempts to maintain herding activities because they are land intensive and they make the best use of the 70% of Valais lands which are grasslands. But only 30% of the revenue comes from these large areas. To increase this figure, attempts have been made to plant new crops. Particularly in the western valleys, the introduction of strawberries and raspberries have brought peasants into a market-oriented agriculture. These fruits are adapted to the mountains because mechanization plays little role in their production. Discrepancies in plains-mountain yields are compensated for by subsidies and elaborate price and import controls. These guarantee a certain income level to the producers. The effect of this change in crops is to modify the pattern of land use. Fields formerly used for grains or hay have been transformed into berry patches. Will the change turn out to be of ecological significance? Officials have not acknowledged any problems. Berry production symbolizes the movement from a broad-based subsistence farming to a specialized market agriculture.

Institutional changes have occurred which alter the relationships within families and among villagers along with environmental changes. The programs which have the greatest impact on mountain communities are those which work to build unified estates from small plots. This policy contradicts the inheritance system which breaks apart agricultural holdings and spreads land among many heirs. Further, the reorganization of land holdings does not take into account mini-ecological zones. Individual holdings are regrouped in one area of the commune rather than being scattered throughout it. This undermines the balancing and equalizing effect of the distribution of parcels.

There is an inherent contradiction between the inheritance system and current policy. Efforts are made to bring estates together. But what happens to the following generation? Will fields be divided up again or will they be passed on integrally to one child? If the goal is truly to rationalize production, it may be assumed that the second process will prevail. Inheritance practices will then cease to function as an equalizing mechanism.

Since this is the first generation of land reorganization, it is difficult to predict where it will lead to. What can be noticed is a very strong resistance on the part of mountain peasants. They are unwilling to exchange their land for other fields. The opposition has been so great that officials have decided to alter the procedure. People would continue to hold title to their land and would simply exchange use rights. This way no one would feel he was giving up his patrimony.[2]

While some policies, like land reorganization, are incompatible with traditional organization, others evolve naturally from the past. Several villages have set up communal stables. By pooling their resources and their time, participants can affront the problems posed by the constant labor demanded by cattle raising. Owners can decide whether to divide the tasks among themselves or to hire cowherds. This is consistent with the long-time commitment to private ownership combined with a willingness to participate in communal activities.

Underlying all these changes in Praz-Fleuri, is the movement from an autonomous, self-sufficient community to a village which is increasingly tied to the external economic and political environment. The process is inexorable and the result a loss of independence. Though the goal of the federal government is to allow the Swiss farmer to continue to make his own production decisions, this is impossible when policies render some crops more profitable than others.[3]

To the extent that many current programs ignore traditional structures and institutions, they hasten the decline of the latter. Attempts to use local organization, such as communal stables, seem to have greater acceptance and therefore success than projects which restructure relations as does the land reorganization effort. Decentralization challenges the government to develop an agricultural policy which is at the same time coherent and responds to particular village level structures.

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[2] J. P. Revaz (personal communication) said this new policy has been tried in an ad hoc way and that the government plans to elaborate new laws taking into account these experiences.

[3] The specialty cultures, strawberries and raspberries, are good examples of this. They were imposed by experts on mountain cultivators who had never traditionally grown them.

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DISCUSSION

Unidentified. Is there impartable inheritance throughout Switzerland!

Wiegandt. Legally, yes, since 1912. The law conforms to the traditional pattern in the Swiss Alps where land was always divided.

H. Schwartzweller (Michigan, USA). I've followed a small German village (some 300 people) that once was inhabited mostly by full-time peasant farmers. They are peasants no more. They're part-time farmers now and the women have become the tractor drivers. Is this true in the village you studied and was it of similar size?

Wiegandt. This village had about 250 people at the start of the nineteenth century and grew to about 400 people about 1920, but has since declined to 250. They're not full-time farmers either. They're now only 20 minutes by road from the canton capital, and the part-time farming they perform is mostly for kitchen gardens. There are only 25 cows left. As in the village you studied, the women do most of the farm work.

Schwartzweller. The Germans also have the concept that landholdings in the small hill farms are a hedge against a future depression or crisis, and there seems to be a deliberate government, as well as family, policy to hold the land in reserve. Is that also true in Switzerland?

Wiegandt. Yes, there seems to be a strong feeling that this is an essential strategy in maintaining their independence, even if it's not "efficient" agriculture.

K. O'Connor (New Zealand). The degree of homeostasis seems great because of the decentralization of government in Switzerland. They seem to delight in systems that slow change. Ecologically, it's fantastically efficient. Please comment.

Wiegandt. That's true if your goal is to preserve subsistence agriculture. Swiss citizenship depends on membership in a community. All the important things that happen to you happen through the commune.

The economic unification of these small units placed them in opposition—both economically and politically—to the outside world. It was successful until the 1930's, when a road was built. But the situation is now changed and you can't consider it efficient by contemporary standards.

36.
The Tragedy of the Commons Revisited: Land Use and Environmental Quality in High-Altitude Andean Grasslands

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This paper examines a high elevation land use system in Peru which exhibits many elements which have often contributed to the deterioration of natural resources. However, steady rather than declining agricultural yields and the lack of erosion and landslides suggest that this environmental degradation which is common elsewhere has not been taking place in this instance. As a heartening exception to the widespread trend of deterioration of mountain ecosystems (Eckholm, 1975), this land use system is worthy of further investigation.

The high-elevation grasslands of southern Cuzco, Peru, are inhabited by populations of Quechua-speaking peasants who engage in agriculture and pastoralism. The rigorous climate and poor soils at elevations above 3600 meters make the ecosystems relatively delicate and subject to rapid and permanent degradation. The strong seasonality of rainfall

and the presence of deeply incised river gorges increase the likelihood and potential damage of erosion. The long history of human settlement in these areas would suggest that these soils would be relatively depleted. Finally, economic and social factors might generate overutilization of the land resources. The economic conditions in this remote portion of an underdeveloped country are not of the type likely to encourage land conservation practices. Technical assistance and access to credit are limited. Since alpaca and sheep wool produced in these areas have been exported for over a century, the inhabitants of these grasslands are firmly integrated into commercial production for export markets. They are thus not involved in subsistence production in an isolated area. Furthermore, rights to pastureland are public rather than private; a number of different herd owners have access to any particular stretch of pasture. Southern highland Peru would appear to be a likely candidate for the kind of situation that Hardin (1968) has called "The Tragedy of the Commons." Seeking higher income, herd owners might crowd their animals on to the publicly owned pasture. Private interest could cause individuals to overutilize a common property resource, leading to its deterioration. The fragility of high altitude grassland ecosystems would make this risk even greater.

In a paradoxical fashion, many of these features which would make environmental degradation of southern highland Peru so likely are precisely the ones which have kept its grasslands intact. The rigorous climate introduces natural mortality checks on animal populations. The long history of human use would appear to have raised, rather than reduced, the maximum sustainable yields of the region. Archeologists have described the long history of terracing and irrigation systems in the area (Lumbreras 1969, Mason 1964). Most importantly, economic and social factors discourage rather than encourage overutilization of land resources. Individuals making rational economic choices in a system with public access to important resources choose to keep herd sizes and the percentage of land under cultivation within safe limits. As Hardin notes, such cases are infrequent.

This paper briefly describes climatic, edaphic and hydrographic features of the mountain grassland ecosystems. It reviews evidence of the lack of environmental degradation. The land use system is presented and the behavior of individual peasants in this land use system is examined.

Several policy implications are drawn. In particular, traditional cropping and grazing patterns are shown to be efficient and adaptive, and hence worth preserving. It is suggested that planners pay close attention to non-Western forms of social organization and land use before formulating and implementing developing programs. Traditional practices offer a number of concrete advantages.

THE ENVIRONMENT

The kind of Andean high-elevation grassland ecosystem know as the puna extends from 8° S. in central Peru to 21° S. in northern Argentina. This report is based on twenty months of field experience in the provinces[1] of Canas, Canchis, Espinar and Chumbivilcas in the southern portion of the department of Cuzo between 14° and 15° S. Shorter visits to 17 other provinces supplied additional information, but the description and analysis presented in this paper is limited to the four provinces listed above.

The puna zone ranges in elevation from 3600 to 5200 m above sea level, although the altitudinal limits of the characteristic grassland vegetation varies somewhat. The puna grasslands are located within the sierra or Peruvian highlands, a belt of high mountains between 250 and 400 km wide lying between the Amazon tropical rain forest to the east and the dry Pacific coastal desert to the west. The prevailing trade winds bring moist air from the Amazon towards the Andes. The moisture condenses and rain falls as this air is lifted over the high mountains. Average annual rainfall varies from about 400 to 850 mm with considerable annual fluctuation. In the province of Espinar, for example, annual rainfall ranges from about 250 to 700 mm, with an average of 550 mm (Orlove, 1977). Rainfall is highly seasonal. Over 75% of the rain occurs from November to March, and the months of June, July and August rarely have any rain (Baker and Little, 1976). These lands are drained by rivers which form part of the Amazonian drainage system. They run through canyons as much as 1000 m deep. As in other high altitude regions, there is great diurnal temperature variation, as much as 45° C, in some areas (Custred, 1973). In one puna study site at 4000 m elevation, the average annual temperature was 8° C, the difference in average temperature between the warmest and coldest months was 2° C, and the average diurnal variation in temperature was 17° C (Thomas, 1973).

During the dry season, the shorter day-length and the lack of cloud cover permit greater heat loss from radiation, and the nightly frosts are correspondingly longer, more frequent and more severe than in other times of the year. Severe frosts tend to occur more frequently in drought years because of the greater heat loss due to the increased lack of cloud cover.

Soil types vary greatly, as surveys by the Peruvian National Office of Natural Resource Evaluation show (ONERN, 1969). They tend to be particularly low in nitrogen. The alluvial fill that corresponds to the more glaciated land forms closer to the tropical rain

[1] The administrative units into which Peru is divided form a three-level hierarchy of district, province and department.

forest appears to be relatively richer in nitrogen and trace elements. The old lake beds of the areas farther to the southwest are poorer in these elements. Soil moisture varies greatly in different localities. In the provinces of Espinar and Canas, volcanic ash settling in large lakes during the Quaternary period produced extremely porous tuff soils. Greater glaciation in Canchis left less porous soils. The more extensive cloud cover in areas closer to the tropical forest also reduces surface evaporation.

Small localized areas under one hectare in size retain considerable surface moisture throughout the year. These areas, known as bofedales in Spanish and oqho in Quechua, occur where a porous aquiferous stratum lies directly above one that is less so. If the interface is exposed by stream incision or tectonic movement, water seeps out from the upper stratum. These areas are more common in easterly regions close to the tropical forest because of the greater porosity of glacial moraines and seepage from the extensive snowfields lying above 5 200 m. These factors also lead to greater frequency of bofedales at higher elevations; most of them occur above 4 200 m.

The vegetation is adapted to this rather harsh set of circumstances (Baker and Little, 1976). The dominant form is the bunch grass known locally as ichu, composed of a number of perennial species of the genera *Stipa*, *Festuca* and *Calamagrostis*. They share a single pattern of growth. The dense, deeply rooted clumps are 5 to 20 cm in diameter and 15 to 60 cm high. The grasses propagate themselves both vegetatively by tillering and reproductively by seeding. The former method is more important, since less than 1% of the seeds germinate. If allowed to grow undisturbed, the clumps take on the shape of a ring, as the outermost shoots grow up each year during the warm moist months of the rainy season. When the ring is between 1 and 2 m in diameter, it begins to break up into smaller clumps.

Smaller grasses and forbs grow at the base of each clump. These plants, at most a few centimeters high, find the microclimate adjacent to the bunch grass favorable. The taller grasses offer some protection from the wind. They increase the available moisture since dew and frost that collect on the bunch grass drip to its base in the early morning.

Other plants are also important. Cushion plants occur in the bofedales. The branches or culms of the plants are crowded next to one another, so that only the tips of the most recent leaves are exposed to the surface. This growth form reduces heat loss during the dry season in these habitats where water is not so limiting. The Kikuyu grass (*Pennisetum clandestinum*) which has invaded fields at lower elevations causes problems in clearing lands for cultivation; it is not found in significant quantities in the punas.

THE LACK OF ENVIRONMENTAL DETERIORATION

The lack of long-term precise descriptions of soil quality in the Andes prevents precise measurement of certain indicators of environmental degradation. However, other sources of data demonstrate that common aspects of deterioration of mountain environments elsewhere in the Andes and the world (Eckholm, 1975) are not present or present only to a limited extent in the puna of southern Cuzco.

Erosion and landslides are virtually unknown in southern Cuzco. The few instances which were observed occur immediately adjacent to roads, where no retaining walls or drains were built. Impressively steep hillsides overlooking deep canyons showed little or no erosion. Terraced fields in locations with slopes over 45° occur in a number of places.

Agricultural and pastoral yield appear to be relatively fixed rather than declining. Written records of yields by individual peasants and landlords are virtually lacking, and aggregate production statistics are brief and unreliable. However, interviews and journalistic reports indicate that yields have changed relatively little. Records of the volume of wool exported from the region show a constant level although these data offer only an indirect measure of actual production (Orlove, in press).

These factors all suggest that the puna grasslands are relatively undeteriorated. Cultivation and grazing have not damaged vegetative cover to the point of inducing erosion and landslides. They have not reduced soil quality to an extent to generate declining yields. Pre-Columbian systems of terracing have been maintained, although few, if any, new terraces have been built and the irrigation systems associated with the terraces have declined.

LAND USE SYSTEMS

Two types of land use systems coexist in the puna grasslands: transhumant pastoralism and long-fallow agriculture. Both types of systems have been practiced in the region for at least one thousand years. These will be examined in turn. The rural populations of the puna grasslands of southern Cuzco are Quechua-speaking peasants, who live in small villages and scattered house clusters (Flores, 1975). Population densities are relatively high (12.9 inhabitants per square kilometer) and nearly constant; the annual rate of rural puna population increase has remained under 1% for several decades. This small increase is in sharp contrast to other mountainous parts of the world (Eckholm, 1975). Some of them own their lands, and others work on private estates known as haciendas which have recently been turned into cooperatives by Peru's Agrarian Reform Program. A fuller description of their demographic history and social organization is available elsewhere (Orlove, in press).

Cattle, sheep, llamas and alpacas are the common herd animals. Although some peasants raise horses, donkeys and pigs, these animals are much fewer in number. Herding activities follow an annual cycle. Transhumance is practiced in conjunction with the seasonal appearance of certain grasses. Individual herd owners have access to pasture through several mechanisms. Some communities and kin groups have permanent rights to grazing lands, which any of their members may use. The laborers on estates or haciendas have access to hacienda pasture for their own animals. In both cases, agricultural fields lying fallow are open to grazing to all members of the community of kinship group or all hacienda laborers. The Agrarian Reform program has expropriated the haciendas in this region and turned them into cooperatives. However, the laborers continue to own herds individually and graze them on the pastures of the cooperative; the herds of the cooperative are also grazed on this land.

The herds are moved to lower areas early in the rainy season, coinciding with the appearance of the new low grasses and forbs in moist areas and around clumps of bunch grass. These small plants form the bulk of the animals' diet, but they are supplemented by other sources. The previous years' growth of bunch grass, moistened by the rains, and the new shoots of the bunch grass which appear late in the rainy season, are also edible. As the rains continue, water flows again in stream beds and collects in small depressions. Certain forbs which are adapted to growing in these moist areas subject to frequent shallow inundation provide still another source of pasture. These plants all begin to dry up after the rains end. The animals are taken to higher elevations in the dry season, where permanent pasture can be found in the bofedales. This pattern of movement avoids the hailstorms and heavy snows in higher elevations during the rainy season. The exposure to greater moisture at these altitudes produces respiratory tract infections in both animals and humans (Orlove, 1977).

The fleece is sheared from alpacas and sheep, and sometimes from llamas, early in the rainy season, so that the wool can grow back during the warmest months of the year. The annual slaughter takes place at the beginning of the dry season, often before the move to higher elevations. This reduction in herd size coincides with the greater scarcity of pasture during the dry season. The first months of the dry season are also the time when meat is preserved by salting, followed by drying through exposure to sun and frost. This freeze-dried meat, known as charki, can be stored for a number of years without significant spoilage.

Important products from the transhumant pastoral production system include wool, meat, hides and dung. Approximately 10% of the wool is used locally by weavers and other artisans. The rest is sold to traders and storekeepers, who sell it to large commercial firms which export some of it. Textile factories located in the cities of Arequipa, Cuzco and Lima purchase the rest (Orlove, in press).

Dung is also an important animal product. It is the most common fertilizer and the principal source of fuel. Sun-dried dung is light and easy to transport and store. Alpaca and llama dung is particularly easy to collect, since each herd has a special site where they defecate.

Agriculture is generally restricted to sheltered places in elevations below 4 200 m, although cultivated plants have been recorded as high as 4 450 m. Major crops include tubers (potato, *Solanum tuberosum*; oca, *Oxalis crenata*; olluco, *Ullucus tuberosa*; añu, *Tropaeolum tuberosum*), grains (quinua, *Chenopodium quinoa*; cañihua, *Chenopodium pallidicaule*; barley, *Hordeum vulgare*), and legumes (fabas, *Vicia faba*) (National Academy of Science, 1975). Fields are owned by individual peasants or landlords. They are acquired through inheritance and purchase. Grazing rights on fallow fields, however, are extended to a larger set of individuals. As in the case of the stock-herding haciendas, these patterns have continued after the Agrarian Reform.

There is a fixed pattern of crop rotation. A field that has been in fallow for several years is first planted with tubers. Other crops are planted in the next year or two, and then the field is left to fallow for three to ten years. Fields are located on slopes rather than on frost-prone flat areas.

Planting takes place early in the rainy season. Furrows are made by turning earth over with a foot-plow (chakitaklla). Grains are planted in the furrows, and tubers and legumes between them. In some areas with gentle slopes, the furrows are placed vertically. They cut across the contours instead of running parallel to them, as is the common Western practice. The shallow blade of the chakitaklla does not dig deeply enough to cause erosion (Gade and Rios, 1972). This pattern of vertical furrows allows the fields to drain in years of heavy rainfall; contour plowing would hold the water, rotting tubers, and in extreme cases producing landslides. The vertical furrows help retain soils through the formation of lynchets or pseudo-terraces (Wade, 1972). These lynchets are an example of the benefits of the long history of cultivation in the area.

Animal dung is used as fertilizer. Experiments indicate that there are considerable increases in yields after application of dung. A study carried out in the district of Nuñoa near the study area showed that a standard application of dung increased the available organic matter in the upper part of the soil by nearly one-third, and significantly reduced porosity (Winterhalder *et al.*, 1974).

The growing season coincides with the rains; the timing not only assures the crops more moisture, but also increases available sunlight and reduces risk of frost. The tubers are cultivated once or twice during the rainy season. Additional soil is heaped up with a small wooden mattock from the furrows onto the ridges. This practice reduces the growth of adventitious tubers and weeds.

The crops are harvested in the early and middle part of the dry season. Tubers are dug from the earth with a mattock. Sickles are used to cut the grains and legumes. They are sometimes threshed and winnowed in the fields, although that is performed closer to the dwellings on other occasions. Grains, legumes and some tubers are stored in sacks and in mud brick enclosures. The high altitude encourages late maturation, however, lessening the period of storage and quantities stored. Some oca and certain varieties of potato are prepared by freeze-drying during the part of the year when hard frosts occur nightly. Peasants consume some of their harvest, and sell or barter the rest. There is considerable demand for agricultural products outside the region.

The crop rotation and the fallowing are both maintained by a single system, the laymi (Custred and Orlove, 1974). This system refers to a set of laymis on the lands of a community.[2] The laymi average between 50 and 250 hectares in area. Each one is divided into a number of smaller, individually owned plots of land. Both the laymis and the plots have boundaries, but they are not fenced.

The laymi sections in a laymi system go through the same sequence of planting and fallowing. In any given year, all the plots in each laymi are either left to lie fallow or uniformly planted with the same crop or set of closely-related crops, such as quinua and cañihua or oca, olluco, and añu. For example, a community with a six-laymi system might have one laymi entirely planted with potatoes, a second one sown with barley, and the remaining four lying fallow. The plots within the planted laymis are privately owned by individual peasants. During fallow periods, however, pasture rights are open to all community members. In the next year, barley would be sown in the laymi which had been planted in potatoes the previous year. The laymi with barley would then pass into fallow, and the land in the laymi which has been lying fallow longest would be plowed and planted with potatoes. The rotation would continue until, in the seventh year, the first would again be planted in potatoes. This long-term fallowing reduces nematode damage to tubers, since the cysts cannot survive for more than three or four years. Ideally the members of each household own at least one plot of land in each laymi, so that they will have access to all the different crops that are planted. In some communities there are two laymi systems in different areas. The particular sequence of crops and fallowing varies from community to community and between systems in communities with two systems. Some individuals cultivate land outside the laymi system. Some of these plots are gardens located inside corrals which are temporarily withdrawn from use by animals. The accumulated dung offers abundant nitrogen, and the walls of the corrals reduce evapotranspiration by protecting the plants from winds. Other individuals cultivate the plots that they own inside a laymi after a shorter fallow period than other members of the community use.

There are several points of similarity between this land use system in southern Cuzco and systems found in the Alps and Himalayas (Rhoades and Thompson, 1975; Brush, 1976). These features include a mixed agricultural-pastoral production system, seasonal movements of herds, complex patterns of land use rights, pastureland held as a common property resource, inter-household cooperation in production tasks and strong community regulation of land use. A similar case has been reported from highland Mexico (Collier, 1975). The specific production techniques and form of social organization differ somewhat, but these underlying similiarities are strong.

ANALYSIS

Different mechanisms have prevented environmental deterioration in the two principal land use systems. Density-independent and density-dependent natural mortality checks keep animal population low. Droughts and heavy frosts tend to occur simultaneously. They raise infant mortality rates by exposing neonates to unusually harsh conditions and by reducing the pasture available to lactating mothers. The former phenomenon is density-independent; the latter has both density-independent and density-dependent components. Infant mortality among lambs increases from its average of 8% to over 50% because of these checks, and figures are comparable for llamas and alpacas (Custred, 1973). In extreme conditions, adult animals also starve. Individual herd owners often slaughter many of their animals or sell them to stock buyers who supply the slaughterhouses in urban areas. Even in good years, herd owners practice an annual reduction in herd size at the end of the rainy season. A particularly dry, cold rainy season will induce them to kill more than the usual percentage. They recognize that the salvage value of an animal that has starved is far

[2] The term community does not refer specifically to the peasant communities (comunidades campesinas) which have official recognition from the *Dirección de Comunidades Campesinas*. It is used to include a variety of forms of locality based organization in which groups of peasant households have *de jure* or *de facto* rights to specific lands (Leeds, 1973).

less than of a living one. In drought years herd owners must purchase additional food precisely at the time when it is most scarce and expensive so they convert their herds into cash (Orlove, in press). Taken in aggregate form, these decisions of individual herd owners may reduce the total animal population of a given area by as much as one-quarter in a single year. The collective access to pasture does not prevent this reduction. Such years of drought and frost occur frequently enough to keep animal population size below the maximum sustainable yield.

The agricultural sub-system has a different set of mechanisms which prevent over-utilization of land resources. A shortening of the fallow period would increase the amount of land under cultivation in any one year. This increase would reduce the application of fertilizer per unit area, since the fixed supplies of dung are not supplemented to a significant extent by artificial fertilizer. The slow biogeochemical cycles in the cold dry punas require many years to restore soil nutrients.

The laymi system discourages individuals from shortening the fallow cycle. It does not entirely prevent it; in certain communities in the province of Espinar the fallow period has been reduced in the last several decades from 12 to 8 or 9 years, alternating with two years of cultivation. It is noteworthy that no system with fewer than eight laymis has been observed to undergo reduction in the number of laymis (Custred and Orlove, 1974). The systems appears to provide a minimum number of years below which the fallow period cannot fall; in this way they prevent environmental degredation.

The observance of laymi regulations is not the product of a traditional mentality which prohibits individuals from changing their customs. Instead, laymi systems offer concrete advantages to individual peasants, despite the apparent illogic and inefficiency of the fragmentation of land holding which it entails. Since all the plots in a laymi are located next to one another, younger and less expert peasants may follow the lead of others in choosing when to plant and harvest. In this way, timing decisions become collective, and all members of the community may draw on a broader pool of experience. The formation of work teams is favored by the proximity of the different plots of land. By being close together and entering into frequent contact, the peasants can coordinate the complex networks of labor exchange more easily during the busy seasons of the agricultural year (Custred, 1972). In addition, the laymi system makes it easier to prevent herders from outside the community from bringing their animals to graze on fallow land. It discourages such encroachments by insuring that the weight of a number of households can be brought to bear against the interloper. Individual households would not be able to exercise sanctions as effectively. Peasants who abandoned the laymi system would find the advice and assistance of other members of the community more difficult to obtain, and they would have greater problems of the incursion of herd animals into their fields.

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37.
Combatting Forage Abuses and Social Problems for Atlas Mountain Berbers

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The aim of this paper is twofold: first, to analyze the forces causing rapid deterioration of rangelands and Berber tribal society in the Atlas Mountains of Morocco, and, second, to suggest an organized program to restore pastures and reintegrate the tribal communities of the region. The major problem is swift, technologically careless transition from a subsistence way of life to commercial sheepraising on hill lands. Both forage and people are impacted by flagrant abuses of the carrying capacity of the land, pushing the Inter-Atlas region toward desertification through deforestation, overgrazing and mechanized plowing of tribally held lands.

THE ECOSYSTEM

The Upper Moulouya River basin (32.5°N, 5°W) lies between the High and Middle Atlas Mountain ranges in central Morocco. Upon descending to 1 500 m as rushing streams, tributaries of the Moulouya form a ribcage of water channels across the foothills below snowcapped peaks. The climate is harsh and semi-arid due to a rain shadow and freezing temperatures in winter. Mean annual rainfall of 200–300 mm decreases with altitude from west to east. Peak shower periods occur in spring and late autumn; snowfall is unusual and winters are often rainless. The hill soils are brown-grey calcareous clays with rock fragments. Above 2 200 m cedar (*Cedrus atlantica*) and live oak (*Quercus ilex*) forests grow on steep mountainsides, but the lower hills have been stripped of trees by man. The slopes are badly eroded, forming rockstrewn "Mars-scapes" of reddish or slate-colored hue. South of the Moulouya River is the Aridh plateau, a windswept rangeland dominated by wormwood (*Artemisia herba alba*) and clumps of alpha grass (*Stipa tenacissima*). These resistant shrubs afford cover to perennial and annual grasses and protect the soil from erosion (Nuttonson, 1961).

Several semi-nomadic Berber tribal groupings, originally from the Sahara, have inhabited the Upper Moulouya since the seventeenth century. They graze sheep, goat and cattle herds on the foothill and plateau collective rangelands. In recent years the numbers of ruminants, particularly sheep, have increased dramatically. The resultant overgrazing has led to considerable deterioration of pastures. Mikesell (1946) estimates the carrying capacity of the Upper Moulouya range at one small ruminant per five ha. Yet today over one hundred thousand head of livestock graze on about 2 000 square km., over twice the estimated carrying capacity of the grass cover.

Sheep are four-fifths of the livestock. The indigenous breed of small hardy animals is adapted to the harsh dry climatic conditions and limited forage. The adult average weight is 35–40 kg. and fleeces weigh approximately 1 kg. Lambing rates are low, half the ewes per year, and lamb mortality is high at one-third of the annual crop (Zakrzewski, 1969). But the urban demand for sheepmeat and wool is so great that sheepraising has become profitable, especially for large stockowners of the Upper Moulouya. Goats survive better in this mountainous environment by browsing foliage when grasses are scarce, but they form only one-fifth of the herds as there is little preference for goat meat. A few head of cattle and some horses and mules are tended

near villages, the latter for transport purposes. Goats and cattle are used to provide milk and butter, while meat of domestic fowl and goats is eaten by the Berber villagers.

A cash economy in sheepraising has emerged over the last two decades since paved roads linked the formerly isolated Inter-Atlas region to the major cities of the Moroccan plains and western Atlantic coast. Larger stockowners have increasingly exploited the Upper Moulouya tribal rangelands by circumventing customary indigenous controls on herd size and movements. Frequently, urban investors associate with Berbers to overstock sheep on the pasture of tribal units, thus evading restrictions on outsider use of the land (Bouyayachen, 1972).

The human population of the Upper Moulouya has also risen rapidly, having doubled in less than thirty years to a total of 46821 by 1971. Rural population density is now 11-12 persons per km^2 and nearly 90% of the people are village dwellers. Four small towns serve as administrative and market centers for the surrounding Berber rural inhabitants (Royaume du Maroc, 1971). The Berber communities of the Upper Moulouya cannot expand territorially as the mountains and steppes surrounding the entire region are already inhabited by other tribes. As their livestock numbers increase, the seasonal scarcity of forages becomes more acute, especially in winter and late summer. This has led to widespread plowing of the rangelands for feed grain cultivation, irrigated cropping of alfalfa near the rivers, and cutting of tree branches and foliage to feed the animals. The area of cultivation has increased exponentially since the 1960's as wealthier stockmen have used tractors and combines to cultivate the hard pasture soils (Raynal, 1961). The resulting denudation of grass cover has raised the spectre of rampant soil erosion leading to a dustbowl effect in case of prolonged drought. In short, massive abuse of the hill lands has resulted from commercial exploitation of tribal lands with inappropriate technology (Nuttonson, 1961).

This accelerating transformation of tribal collective lands into open ranges and cultivated areas must be placed in its historical perspective. The Inter-Atlas Berbers have long been politically distinct from the central government of Morocco's Arab kingdoms. France conquered the Sultancy of Morocco in 1912 and created a Protectorate government. Modern military forces penetrated the Atlas regions in the 1920's and met with strong Berber tribal resistance. The Upper Moulouya Berber federation was finally overwhelmed in 1934. Since then the tribes have exchanged annual vows of fealty to the Sultan of Morocco in return for his perpetual protection of their rights to the collective rangelands. However, the French introduction of centralized administration via military rule has opened the door to the outside takeover of Inter-Atlas natural resources (Guillaume, 1946).

At first private lumber camps exploited the large cedar forests on the mountainsides, and the alpha grass on the plateau was cut for paper production. Since World War II these resources have been declared part of the national domain and are patrolled by armed rangers. More recently, small government mining and lumbering operations have been carried on, but the rangelands have suffered the greatest change in land-use pattern. Conservative tribal forms of collective land tenure have given way to illegal private expropriation. The better-watered uplands have been subdivided into fields for cereal tillage. After Moroccan independence from France in 1956, this landgrab extended to the semi-arid foothills and plateau rangelands. Deep plowing with tractors has since reduced the grazing areas by half and seriously eroded soils, but as yet goes unregulated (Carter, 1966).

In the last two generations most of the tribal groups settled in villages along river tributaries of the foothills and terraced the banks for irrigated tillage. Each village community has access to the surrounding collective range land, but is prevented from engaging in transhumant migration by government edict. The rigid administrative districts set by administrative fiat have divided off the foothills from the plateau and higher mountains. The formerly semi-nomadic Berbers were thus sedentarized, and changes in land use have altered their economic basis for survival. A monocultural cash economy of sheepraising for urban markets has led to concomitant increases in importation of manufactured goods and refined foods. Meanwhile, traditional social and political cohesion within tribal units has given way to class divisions between the large stockowners and landholders on the one hand, and small farmers, graziers and agricultural workers on the other (Table 1).

TABLE 1. Sheep holdings of Berber households around the Aridh Plateau by socio-economic strata[a]

Socio-Economic Strata	Households (Percent)	Sheep Holdings (Percent)
Large stockowners (200+ head)	3.0	27.0
Large landowners	9.0	18.0
Small farmers	22.0	14.0
Small grazier-cultivators	49.0	31.0
Nomadic herders	5.0	9.0
Landless agricultural labor	12.0	1.0

[a]Adapted from Teitelbaum, 1973.

ECONOMIC AND SOCIAL CHANGES

The Aridh Plateau is located between the Moulouya River and the High Atlas Mountains; it has long been a collective rangeland grazed by mixed herds from the surrounding Berber tribes. Formerly this wormwood-dominated land was used primarily for winter grazing as part of a seasonal system of transhumant movement between the river and the mountains. However, seasonal pastures are no longer available due to administrative boundaries restricting the space to local settlements. Today the Aridh Plateau is grazed year-round. In a study of 1041 households surrounding the plateau, data on sheep and other livestock as well as land holdings were obtained for over 4000 people, about 10% of the Upper Moulouya rural population. The household survey was conducted in 1971–72 in connection with a rangeland grass-seeding scheme sponsored by the U.S. Agency for International Development (Fallon, 1972). Table 1 describes the socio-economic stratification of these 62 villages.

More than four-fifths of the households practice small-scale cultivation on hilly plots along the tributaries of the Moulouya River. Slightly more than half of the households engage in livestock raising, but only a small fraction still practice nomadic pastoralism. The vast majority of small graziers are sedentary and sheep husbandry is dominated by a few large stockowners and landholders who control nearly half the commercial livestock. Large farmers use the range to grow feedcrops of barley and maize and produce alfalfa on irrigated land. Small farmers and graziers make up the overwhelming majority of the population, but possess less than half the livestock and little more than half the land. Some small farmers also cultivate land for large landowners. At the bottom of the new hierarchy are the landless agricultural workers who gain a livelihood as seasonal farm workers and herders. Many are recent immigrants from the droughtstricken Sahara who now constitute one in nine of the households (Teitelbaum, 1973).

Observation and data analysis show that the modal-size Berber household in this study contains 4–6 persons forming an elementary family group in three-fourths of the cases. The remainder consists of larger extended family households which are most frequent among the wealthy; men of substance are most likely to practice polygamy and to keep their married sons within their family group. Although large stockowners have upwards of 200 sheep, a typical small farmer or husbandman owns 15–20 sheep and a few goats as well as a small plot of land. Most households possess a mule or horse for transportation and farmers have one milch cow. From their small flock the Berber household unit derives its annual supply of wool for clothing, bedding and rugs, its milk and meat, and cash from the sale of surplus lambs. Those without land or animals are dependent on sharecropping and wage labor for a living (Bouyayachen, 1973).

HUMAN PROBLEMS

The human consequences of economic change and ecological abuse have been remarkable. Berber extended families have declined in size as the seminomadic way of life disappeared. The exchange of women in marriage formerly functioned to link in-laws to one another across tribal and geographic boundaries thus permitting transhumant herd movements into one another's territory. Today, marriage no longer serves the purpose of arranging grazing patterns. Tribal groups have lost genealogical depth and the inter-tribal federations are without political authority since their suzerainty has been abrogated by government (Marx, 1974).

As a result, divorce rates have increased to record levels leading to the breakup of over one-third of a sample of study marriages in the Aridh Plateau area. Divorce is traditionally easier and more frequent among Inter-Atlas Berbers than among rural tribal Arabs in Morocco due in part to the independent status accorded women by Berber customary law. However, recent developments have tended to unravel the affinal ties between families and within communities to a marked degree. Commercial prostitution has emerged with the introduction of a cash economy, as young divorcees of tribal origin migrate to the market towns of the Inter-Atlas to ply this trade. The process has been encouraged by a concentration of military barracks in Upper Moulouya towns since the French conquest of the region, and it has built upon customary roles played by Berber women as dancing girls and courtesans. With independence, increasing numbers of urban men travel to the region by auto to enjoy the open brothels and to consume alcoholic beverages without fear of arrest (Teitelbaum, 1973).

Installation of dozens of marketplace brothels has been abetted by some government officials and evolved into a specialized income-producing trade. In fact, some of the proceeds of prostitution are invested in sheepraising on the tribal rangelands, thus increasing the stock and contributing to forage abuses. Hence the Inter-Atlas has become known for the exploitation of its human resources as well as its land and livestock. Unable to develop traditional stable family life through marriage, divorced daughters of the rural poor are the most likely recruits into prostitution even though it is considered socially shameful. A few of the best female courtesans have become nationally famous entertainers attached to the royalty and high government officials in the cities, thus encouraging others to follow them into a career which offers dreams of stardom. But, for

the majority of women it is a lifetime trap of increasing misery and disease.

As pointed out by Raynal (1961) venereal disease has tended to induce sterility among women. This and divorce are major factors limiting population growth in the Upper Moulouya. With the decline in sexual mores, illegitimacy has become common and many children are orphaned or abandoned. A few Christian missionaries have taken on the function of caring for sick and parentless children—a most unusual development in a Muslim society.

GOVERNMENT PROGRAMS

Recent attempts to improve the rangelands and manage sheep production in the Atlas region have failed due to poor organization and opposition by graziers and cultivators. Small herdsmen and nomads fear the Ministry of Agriculture-U.S. Agency for International Development grass-seedings and sheep-breeding trials which they suspect are preludes to expropriation of their lands. Prosperous landholders prefer to raise grain on the collective lands using tractors rather than allow the range to be used primarily for grazing. Large stockowners treat the pastures as a "free good" for their herds of sheep. According to Fallon (1972), very few Berbers are willing to participate in forage demonstration projects; some have resorted to harassment of government projects by plowing up land slated for grass-seeding, removing fence perimeters and even burning range management depots.

These failures stem in large part from a combination of mismanagement at the local and regional administrative levels, and compartmentalized bureaucratic rigidities of the central government. In attempting to develop economically Morocco has adopted a French model of regional planning to replace the French military system imposed on the Atlas Mountain provinces. Although organized along the lines of a modern nation-state, allegiance to the central authority is mediated by traditional tribal fealty to the monarch and his Islamic line of descent. Hence the Berber populations of the Inter-Atlas are free to harbor secessionist tendencies from the Arab state while under quasi-military rule.

Central government policies since independence have encouraged the development of private enterprise and market commerce which has come into conflict with the customary system of collective land tenure on the Berber tribal lands. This has led to maldistribution of wealth and abuse of the natural resources. However, no institutional mechanisms exist to redress these inequities or to command the adherence of the population to government programs of technical assistance (Waterbury, 1970).

In point of fact, the Upper Moulouya no longer contains tribally controlled collective ranges. The hills and plateau are heavily overgrazed and a stockman cannot maintain a large herd without exploiting the land for cereal production of feedstuffs. As a result of plowing, forest-cutting and overstocking, the system is evolving into a "tragedy of the commons" (Hardin, 1968). However, this common pastureland (unlike the model proposed by Hardin) is not inherently unmanageable; rather, the tribes lack a means of enforcing their usufructory right against incursions by commercial entrepreneurs. The resulting land grab makes for abuse of the fragile natural environment far more quickly than the increase in human population. The real population pressure is an external one, the rising demand of urban people for mutton and wool which in turn has spilled over environmental degradation on the Inter-Atlas. The Berber society has undergone societal atrophy as a result of government-tolerated misuse of its collective lands.

A PLAN FOR REGIONAL DEVELOPMENT

By following certain criteria a rural development agency can conserve the soil and vegetation of the Inter-Atlas, improve animal productivity and renew the tribal social system. To achieve this set of goals, tribal rights in collective lands should be reinstated rather than eliminated. Hills and plateau should be limited to use by transhumant herds on a seasonal basis once again. Careful breeding, culling and veterinary control of livestock will improve yields. Feed crops of high nutritive value can be raised to supplement forage when grasses are scarce (Nuttonson, 1961). Provision of these technical services requires land reform and prevention of outside use of the lands. In short, range management in the Upper Moulouya demands attention to social problems as well as biological interrelationships.

Although Berber society cannot return to the semi-nomadic, tent-dwelling ways of the past, a more modern form of transhumant sheepherding is now possible. The current rigid district boundaries prevent a cyclical migration of herds between the foothills and the plateaus. The animals are concentrated in areas where there is little food at certain times of the year. However, a new system of collective land use could build upon the geography of tribal settlement. Village communities are located like beads threaded along the tributaries of the Moulouya River. They form longitudinal chains from the foothills to the river channel with its tributaries as their cores. Tribal chains follow geomorphology rather than disjointed administrative jurisdictions. By redrawing district boundaries to include entire tributaries, herdsmen from all the villages along a stream would have access to summer grazing in the High Atlas and winter grazing on the plateau.

Each transhuming segment, termed a Rib, would include a few thousand people from over a dozen villages of associated tribal groupings as well as

a manageable portion of the collective rangeland. Rib members could elect representatives to a range management organization in order to prepare and control the seasonal transhumance of livestock, resolve disputes between members, and communicate their problems to responsible government officials of a rural development agency. A federation of Rib units would form a Rib-cage and include the entire Upper Moulouya Territory. (These territorial divisions are named after indigenous Berber concepts of social structure, Hoffman, 1967). At a higher level of organization the Rib-cage federation would deal directly with all government agencies and adjoining populations.

The rural development agency can provide federation members with access to economic and technical assistance and human services such as better sanitation and health services. To be most effective it should be organized as an interministerial task force to coordinate expertise on all aspects of Inter-Atlas problems, legal, administrative, economic, environmental, agricultural, health and social. For example, prostitution and venereal disease problems may be viewed as closely tied to economic inequalities, land tenure conflicts, divorce rates and administrative laxness. By policing brothels and eliminating use of alcoholic beverages, the vice activities in the market towns could be significantly reduced. Outsiders could be prevented access to the brothels and the rangelands; also, tractor plowing could be severely restricted. With the reintroduction of managed transhumance, marital bonds may be strengthened, reducing the incidence of divorce that currently propels divorced women into prostitution. Reduced demand for sexual services will also permit the revival of tribal Berber norms opposing promiscuity and alcoholism. As economic conditions in sheepraising improve for small graziers the tillable land could be redistributed to the farmers and agricultural workers. Under these conditions, measures to improve the productivity of herds and initiate range management programs may prove more successful. Also, health measures could be introduced to control venereal disease and provide better sanitation and nutrition.

A major element in building the redevelopment will be to find ways to enforce restrictions on the use of rangeland and to eliminate outside investment in livestock. This will assist in reducing the size of herds and will prevent the domination of the region by large-scale sheepraisers. To return usufruct of the hill lands to the Berber tribal units will require close coordination between the rural development task force and the Berber federation (Rib-cage) organization; in short, a new orientation in Moroccan governmental planning for regional progress and conservation of hill land resources.

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38.
The Evolution of Country Planning As an Alternative to Urban Planning for Rural Areas

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The Piedmont Environmental Council (PEC) is a non-profit citizens' organization, supported almost entirely by private contributions and federal grants. It has been in existence since 1973, and currently has a staff of seven: four professionals, one administrator and two secretaries. Although the Council has no governmental or legal authority, it operates in a loosely comprised nine-county area of piedmont northern Virginia, roughly about 90 000 hectares in size. It was established to find a new way to plan for the use of land, one which is relevant to undeveloped agrarian counties, and which might regulate the use of land along conservation principles. Neither is being done in most rural areas of the United States.

PEC is a conceptual experiment that arose from a concern by community leaders and citizens that perhaps current land use planning is inadequate to provide a balance between development on one hand and to stewardship for land resources on the other. It is an experiment which aims primarily at revision, both of the planning system and its goals, and of societal attitudes toward the "growth is good" syndrome of the 1950's and 1960's. It is also an experiment which has a very excellent chance of succeeding, as I hope to point out.

There are five primary causes of the developing pressure on the use of land in the Piedmont region:

1. Water authorities with extra-jurisdictional powers of eminent domain.
2. Sewer authorities with plans for maximum population growth.
3. Power companies seeking to ever increase levels and efficiency of service.
4. Highway departments with plans for new and/or better roads, bridges and interchanges.
5. Speculative developers, with economic market analyses, who seek lower land costs and higher profits.

Frequently these agencies are not interested in a resource-based land use system or the concerns of the people of a region: they have interest only in obtaining their aims with minimum opposition and trouble. Their independent actions and accomplishments do not appear to directly affect the use of rural lands, and are usually justified on such grounds. But taken together and considering what each agency makes possible for the rest of society, the effects can be ponderous. The old maxim which says "growth goes where the sewers go" actually holds for all five agencies!

A REGIONAL PROBLEM

In PEC's nine-county region, all five of these agencies have been working their will for approximately two decades. We cannot say that we live in hill lands now, but I am reasonably sure that in 1955, Leesburg and Warrenton were still considered by many Washingtonians to be Virginia hill towns. In 1965, Reston emerged in the middle of gently rolling farmland in western Fairfax County; now Reston is considered by some residents of Sterling Park and Sugerland Run (farther out) to be an "inner suburb," only 17 miles from the Washington Monument. In 1876, all were several hours' journey from the nation's capitol!

In 1876 we were a developing nation, with a few cities sparsely placed at strategic locations along the coasts and rivers for transportation purposes. Today we are predominantly a nation of commuter regions, with the hill lands being those most attractive for residential purposes and, to most urban workers, the rural destination is well worth the time expended in getting there. PEC's region has commuter colonies and weekend nature-lovers' habitations as far away from Washington as Malvern in Madison County (100 miles), or Wilderness in Orange County (75 miles). Our problem is simply Washington's failure to provide for and protect its once-ample recreational facilities and once-beautiful in-town residential sections. The PEC region has become a playground for tourists and commuters.

PEC's nine counties are bounded on the west by the summit of the Blue Ridge and its Skyline Drive, a spring and fall paradise for millions. The region is bounded on the south by the James River below Charlottesville and on the north by the Potomac. Both rivers are sanctuaries for fish, wild animals, and a host of recreational activities for people. On the northeast, the region is currently bounded by the mass of metropolitan growth along major arteries into the foothills. The Shenandoah National Park is its *prima facie* scenic area, but Virginia has seen fit to name no less than 27 critical environmental

areas in the region, all associated with scenic hills and streams.

The region's population was 200 000 in 1970; in 1950 it was but 121 000. In 1970, 72% of its population was classified by the census as rural; there were 5.0 ha of land for every person in the Piedmont. One projection holds that the population will be 250 000 by 1980; others say it has already exceeded this figure.

The region's problems are not unique: too much growth, and too little ability to channel it properly. PEC was designed to overcome this through education, research, application and implementation of new technologies in land use, in conservation and in design. Its program currently consists of three major areas of study on these problems:

1. The preservation of farming and farmland, and the active stimulation of a healthy farming economy, to protect rural appearance and character.
2. The conservation and preservation of non-farm open space, including forests, streams and land that is in a state of ecological succession, or returning to a natural state ecologically, to prevent sprawling growth patterns and to protect scenic resources.
3. Stimulation of town and village growth and development to prevent continued decline of rural population centers and decentralization of rural services and living areas.

The specific tasks of this program are constantly in a state of change depending upon the success of the effort, but the three areas are considered broad enough in scope to deal with the various social, political, economic, or physical issues that emerge in rural areas when development proposals are in conflict with society's goals.

FARMING: PRESERVATION AND STIMULATION

The most important long-range use of land in the Piedmont is for farming, provided population continues its increase over the next 100 years. Due to the poor economic conditions faced by farmers and to the continuing artificial increases in land valuation, the number of productive farms in the region has declined by 17.4% in the most recent five-year period alone! The amount of land devoted to agricultural production declined by 11.8% in the same period, 1964–1969 (U.S. Census, 1970). At these rates of decline, some may wonder whether farming will go completely out of existence in this foothill area over the long range.

Whether it will decline that much is not really the issue, however. What is at issue is the effect of a rapidly disappearing farm economy and a simultaneously emerging urban economy upon the rural society, rural employment and the rural land use pattern. PEC's staff observation has been that the quiet, unhurried life and slow pace thought to be characteristic of rural areas are disappearing even more rapidly than the farm economy. These trends can only be slowed through fundamental changes in taxation and land valuation policy and initiation of a program to educate the inhabitants of the rural area on the potential advantages and disadvantages of the growth and development syndrome.

In 1973, PEC organized its Farm Economic Study Committee, devoted to working to resolve the farmers' dilemma. Several papers, conferences, seminars, and general speeches have pushed the issue before the public in an effort to educate citizens and to change their attitudes toward unrestricted growth. The Committee also has studied the tax and valuation situation, and some members have been instrumental in helping to formulate legislation to alleviate the farmers' land and estate tax burdens.

PEC maintains close liaison with the Cooperative Extension Service of Virginia Polytechnic Institute and State University at Blacksburg. Resulting from this has been a whole series of land use seminars devoted to developing a more equitable system of land use regulation for rural areas in particular. As an example, Virginia's rural farmers will soon begin to enjoy the full benefit of a reduction in property taxes and assurance of long-term stability of farm use of land through participation in voluntarily designated agricultural districts, largely due to the efforts of these two groups. In addition, the governor of Virginia has appointed a new Land Use Advisory Committee to deal with the evolution of a statewide land use system.

PEC also has worked closely with several of its county jurisdictions to find innovative planning techniques to protect their primary agricultural lands from the threat of non-agricultural development. Indeed, the theme is pervasive in every land-oriented program PEC conducts: Save Farming!

Two of the planning approaches deserve mention here. The first, for Loudoun County, is essentially an environmental resources inventory of land in the county which should be reserved as open space. The study calls for the establishment of scenic districts in areas which are primarily agricultural. Special review procedures would be established to regulate future development in accordance with a stated objective of keeping the district clear of intrusion of disruptive non-agricultural uses. The study has been accepted by the county and will be included with changes in the next revision of its comprehensive plan.

The second, a scenic quality inventory for Fauquier County, also is a part of a plan revision. The study made an inventory of all lands in the county and assigned a Scenic Quality Index number to every portion of the county. The index contained three separate scales: one each for agrarian land, wildlands and settlement areas. The development of the scale

involved extensive participation both of the public and of local government. The county now seeks to make agricultural and other scenic areas a part of its zoning system, with special restrictions pertinent to such areas.

The successful protection and stimulation of farming in the Piedmont area will depend very heavily upon the acceptability of such procedures. PEC's future program provides for a continuation of this focus for at least the next two years.

OPEN SPACE: CONSERVATION PROGRAMS

In addition to farming, protection of non-farm open space is another primary area of PEC's conservation program. Forested land, streams, ponds, lakes and unused open land comprise approximately 45% of all land in the region. Near the Washington fringe, much of this land is held in corporate or speculative ownership. The high valuation of such lands makes it practically impossible to obtain them under a program of public acquisition, so the lands generally await development. In more remote areas, such lands are still ripe for first and second home development regardless of location or availability of services.

There is little anyone can do when the developer is ready to begin construction, or where the nature of zoning for such lands is purposely flexible to the point of allowing virtually any urban type of development through the permitted uses section or through rezoning. Most American property owners insist upon freedom to use the land or develop it as they wish, and the more active developers are willing to spend vast amounts to defend that freedom. The conservation of open space is not usually uppermost in their minds as they pursue their aims.

PEC has been working for two years to develop a series of private initiative open space protection programs, as well as to find new ways to use the planning system to protect open space. The studies generally seek ways to provide benefits through the elimination of market value from open lands, thereby reducing the property taxes on such land. While this has the advantage of allowing more people to participate in open space programs by reducing their need to turn to speculative development, it has one inherent danger: it may cause the value of land, already low in rural areas, to decline even further. This might open the gate to speculation. So PEC seeks to accomplish a multi-faceted program of conserving open space: through planning, through voluntary gift, through creative use of condemnation or through bartering. Although virtually no progress can be made on the latter two, due to their complexity, a great deal of progress has been made on planning and voluntary gifts.

Beyond the two examples cited above, there have been several similar achievements which have helped local governments and their planners to set in motion the workings of a sound open space policy for their jurisdictions. But more important than these has been the general enthusiasm of private citizens for giving or donating the development rights to their property voluntarily to a state or national agency set up to receive them. Historic Green Springs, faced with plans for a state prison facility and for extensive vermiculite strip mining in its area, managed to secure private donations of scenic easements on more than 19800 ha of land as a preventive measure. PEC has conducted three scenic area studies to date which provide a plan for the coordination of scenic easement donations by private individuals wishing to override the zoning statutes of their area by permanently eliminating any possibility of unwanted physical growth. At the time of this writing, approximately 9400 ha have been protected as permanent open space.

Scenic easement programs have immediate attractiveness to both local government and private citizens, since they involve no maintenance costs to the county or city, and since the donor retains all remaining rights to the land. The land is immediately protected from development considered to be out of character with the area, and the owner's property tax assessment declines as a result.

TOWNS AND VILLAGES: THE KEY TO FUTURE GROWTH

Approximately 65% of the inhabitants of the Piedmont Region served by PEC live in small towns and villages, with the remainder scattered throughout the area on farms and small road-related residential areas. According to PEC research, town and village inhabitants occupy less than 5% of the total area of the region. The towns and villages of rural areas are not, in general, densely settled, with a majority of homes placed on rather large lots. Sprawl has not been a significant problem in the past, but there is an increase in sprawl-type growth on an estimated par with metropolitan areas, especially in towns within metropolitan shopping and employment influence.

Industrial and commercial growth is minimal in rural areas, yet like the big city, such growth is attracted by the economic advantages of open land development and lower county taxes in the rural fringes. County and town officials still generally adhere to the old chamber of commerce philosophy that industrial and commercial growth is essential to the local economy and tax base, which is certainly true. But, as there has always been plenty of land for development, there has been little historical concern for the evolving physical pattern of either residential or commercial development. While towns struggle for their existence, bedroom commuter colonies, country club estates and regional shopping

centers spring up along major arterial highways throughout the rural countryside.

The towns of rural areas provide a significant opportunity to effectively soak up much of the sprawling development now taking place. This "sponge" capability, as it might be called, can accommodate up to 75% of a community's 20-year projection for population growth without intruding significantly on the community's peripheral open space reserves.

Through careful design and through a change in attitudes on the part of landowners toward the proximity of neighbors and density of habitation, a given town may find the means to increase its population internally and to improve its living environment at the same time. PEC has conducted several studies with this goal in mind. At the county-wide level, a study has been made for all existing towns and villages of their potential internal development capacities, and it has shown that approximately 70% of the 1990 population growth projection of the County Comprehensive Development Plan might be accommodated in this manner. Another study, of a single town, suggests that approximately 70 new habitation units might be added to the 20 existing units, along with appropriate proportions of new commercial and institutional space on an 4.8-ha central area site. The population of the overall area of the town might be increased by as much as 500% without extending the town's present corporate boundaries or building above two stories.

Other studies show that economic viability and living quality can be improved substantially through less ambitious cosmetic treatment of the visual appearance of the town, and through preservation of its architectural and landscape resources. These studies have clearly shown that the development of rural towns and villages provides the key to the growth problems currently being faced by the vast non-metropolitan rural regions of America. Social, economic and physical environmental issues are most likely to be resolved through a comprehensive town development process.

THE EVOLUTION OF RURAL PLANNING

PEC's farming, open space and town studies suggest that, in view of the apparent need for a vastly changed approach to land use planning for rural areas adjacent to population centers, there are some viable approaches under exploration. Conservation of scenic areas, productive agricultural and forest lands and of air, mineral and water resources can only come about as a result of an integrated approach to development and resource management. A new planning process should seek to coordinate development proposals with maintenance of the farming industry, open space protection, and the existing town and village infrastructure network. It should seek to guide decisions of government toward an efficient physical pattern and balance the provision of public services with the tax revenues which underwrite them. The system needs to be responsive to societal needs and pressures, political realities, and economic constraints, and to provide a workable structure for incorporating these in the decision-making process. Above all, the planning system needs to be attentive to the pluralistic and shifting attitudes of individuals in each community as they relate to efficient land utilization and careful management of land-based resources.

If the "country planning" prescribed above becomes a reality, some planning goals for the rural regions and hill lands will almost certainly become more attainable:

1. We will be able to maintain an economically sound and socially rewarding agricultural community.
2. We will be able to provide a balance between development, land use and community services.
3. We will be able to prevent the loss of rural populations to the more attractive urban employment centers.
4. We will be able to protect those rural area resources which provide the basis for virtually all economic and social activity.
5. We will be able to control and protect the pattern of land use in rural regions, as well as the natural and historical context which sustains it.
6. We will be able to look with pride upon the "quality of life" our rural areas provide, and to point to a rural planning process which creatively and aggressively produces that quality of life.

Land use planning does not currently attain these goals. It has taken three years to develop an understanding of the region's social and economic system, and to specify goals for its management. Given the entrenchment of the political and legal processes which govern these systems, it may take many more years to work out the means, the technologies, and the approximate directions for attitude shifts in order to obtain the goals.

39.
Nute Ridge—Half a Century Later

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Nute Ridge lies on the crown of a long broad hill about six miles north of Rochester, New Hampshire, a small industrial-commercial center of approximately 20 000 people. The Ridge is located in the town of Milton, population in 1976, 2 200 (1 400 in 1926). It is bisected east to west by a rural road running from Milton to Farmington, which is the nearest general shopping area. Farmington has approximately 3 800 people. The generally north-to-south orientation of the Ridge is traversed by a single highway on the southern half and by double or parallel roads on the northern half. It is along this axis that approximately 70 dwellings are scattered, with adjacent fields sloping gently downward, giving long views to either the east or the west.

Old stone walls run off into the woods or encompass the few remaining small cleared fields. The soil is for the most part stony loam, a kind of general mixed glacial till with occasional granite outcroppings. The Soil Conservation Service classifies it as "Paxton-Hollis-Woodridge Association, deep to shallow, predominantly well drained or excessively drained on rounded hills of the uplands."

The forested areas are third and fourth generation mixed hard and softwood species with occasional good stands of white pine.

HISTORY OF THE RIDGE

The Strafford County map of 1856 identifies Nute Ridge as a major community labeled Goodwinville. Today it is without identity on any map—only the marker on the main road in the valley reading "Nute Chapel" would direct one to it.

Governor's Road on the Ridge is an ancient highway which originally was the main route from Portsmouth to Wolfeboro. It was constructed under the administration of Sir John Wentworth, last of the Royal governors. Some of his descendants were still located along it ten years ago (Weeks, Corrow, Downey, 1967). It is helpful in understanding the Ridge to know something of its history. The following is taken from University of New Hampshire Extension Circular 68, *Nute Ridge—The Problems of a Typical Back-Town Community* (Woodworth, 1927):

> The setting of Nute Ridge was a repetition of earlier settlements elsewhere. A few families from Durham and Madbury, thirty miles to the south, moved to the Ridge in 1800, and soon after that, others arrived from nearby but older settlements From 1800 to 1835 the people were busy building houses and barns and clearing land, but the work of developing the region agriculturally came to an end in about 1835 to 1840. At this time the energies and interests of the farmers turned from agriculture to manufacturing. Prior to 1835 farmers produced food and clothing for their own families and had a few products to sell or exchange for the few things that had to be purchased. Most of the energy was used in clearing land of trees and rocks, and in building comfortable homes and barns. These people, like all pioneers, were busy making conditions more favorable for better farming. (Summarized from an old clipping from the *Rochester Courier*, Rochester, N. H.)

(Note: The information contained in the second sentence appears to be inaccurate. Governor's Road was built earlier and in at least one or two cases, there is substantial evidence that some dwellings were built before 1800.)

From 1835 on, one of the chief occupations in the area was making shoes. Weekly supplies of uppers, soles, linings, and other materials were available, and farmers took these supplies to their homes and brought back finished shoes. Women and children were wont to do their part and, as a result, the home shoe business grew. Eventually two major shoe shops were established on the Ridge. This manufacturing later moved to the villages of Farmington and Milton to take advantage of the water power developed there. Although no longer dependent on water power, shoe manufacturing continues to be a major industry in the area.

This brief history helps to account for the nature of the present agriculture of this region. For nearly a century, farming has been of minor importance, and the farms never have been equipped with modern machinery.

The Ridge is named for Lewis Worcester Nute, a resident born there about 1820. He left his home on the Ridge and made his fortune in Boston in the leather trade. He later returned and on his death (1897) left $10,000 for the construction of Nute Chapel—the community church still in use on the Ridge—plus an endowment of $30,000 for its support. He also established a trust that provides for residents of the Ridge free burial plots in the cemetery located at the crossroads.

THE RIDGE A HALF-CENTURY AGO

In 1926 the New Hampshire State College of Agriculture and the Mechanic Arts had existed as the University of New Hampshire for only three years when Professor Harry C. Woodworth, economist for the Agricultural Experiment Station, wrote Extension Circular 68. In setting forth his interest, he stated:

> Many of the agricultural communities of New Hampshire are in a sound condition, and no one seems to question the permanence of this situation. Other communities are so depressed economically that few would doubt that reversion of the field land to timber should be the logical trend. But there are communities or groups of farms between these extremes where one is not so sure of the case. Nute Ridge is one of these.
>
> This Ridge gives one the impression of a once prosperous farm community which has been slipping back for some time and yet its location, two miles from Farmington, and seemingly good fields of tillage land make it difficult to understand why it should not be as prosperous as similar communities in other parts of this State. Nute Ridge, as evidenced by the splendid buildings and the general beauty of the region was once a prosperous and well-populated community.

Woodworth obviously felt that if the problems of this back country hill community could be understood and a solution found, valuable guides to communities similarly situated would be provided. He was a man of wide curiosity, as his list of publications while at the University attests. These range from highly technical time-motion studies to delightful speculations such as those concerning Nute Ridge. That Nute Ridge puzzled him, as well as intrigued him, is evident from the first paragraph on the final page of Circular 68, "After mulling over conditions in Nute Ridge for many months, the following conclusions have been reached . . . ."

> 1. Young people should not be expected to remain or return to a community purely on the grounds of sentiment. The happiness and welfare of people should be the objective.
> 2. In New Hampshire, with plenty of rainfall, land not worked will soon grow to brush and can be redeemed only at great expense.
> 3. Nute Ridge, as evidenced by splendid buildings, was once a prosperous and well-populated community, but at present there is every evidence of decline.
> 4. The people are, for the most part, intelligent and refined, but they have grown old on the job and there seems to be none to take their places. The atmosphere engendered by a declining agriculture saps the energy of even the most ambitious.
> 5. If the general agricultural situation remains for many years as it is, certainly the country will not need the crops from Nute Ridge, and perhaps the best thing to do would be to set out white pine on the present tillage land.
> 6. Without some organized guiding influence, Nute Ridge will cease to be a community.
> 7. The fine brick chapel on the Ridge—with library, equipped kitchen, and basement rooms—has possibilities of an ideal community center.
> 8. Dairying will succeed better if combined with potato production. Reorganization will necessitate grouping several farms into one. Nearby cities offer good markets.
> 9. The region should be especially favorable for the organization of poultry farms.
> 10. Even if the community ceases to exist, timber will be of no small importance.

What happened in the half century since Woodworth's visit to a typical back-town community? Were his suggestions for community adjustment ever followed? How good were his predictions of the future of Nute Ridge? How different is Nute Ridge today from the summer of 1926?

GENERAL SUMMARY OF FINDINGS—THE PAST

This study represents not only an update of Professor Woodworth's 1926 survey, but for certain items also allows comparisons with data acquired from a detailed 1856 map and from a complete population and dwelling inventory conducted in 1967. This latter information was published as *Nute Ridge Revisited* (Weeks, Corrow, Downey, 1967).

All evidence appears to suggest that this back country upland area reached the peak of its development between 1850 and 1860 when there was an active community of approximately 55 households, a general store, post office, schools and employment in two shoe shops, one of which hired approximately 75 people. From this point on there is a steady decline, which appears to have reached the bottom between 1920 and 1930, the period during which the first Nute Ridge study was being made. At that time it was possible to identify only 26 year-round households of which 22 had heads 60 years of age or older. At that point the Ridge population was 51 persons, with only seven under the age of 18. Fourteen of the households at that time were headed by widowed or single persons. Subsistence agriculture characterized the area with 17 units identified as farms with a total farm inventory at that time of 16 cows, 16 horses, 20 sheep, 1 pig and a few chickens. The only crops other than hay were 3.2 ha of potatoes and 3.2 ha of grains.

GENERAL SUMMARY OF FINDINGS—THE PRESENT

The population of the Ridge has nearly returned to its 1856 level. There are 49 year-round residential dwellings, an increase of 23 since 1926, and 14 seasonal dwellings. Gone are the store, post office, schools, etc.; however, the church and Grange are

still there. Church membership is small and the turnover of ministers frequent. However, there is a Sunday school and it is probable that it will show some growth. Unlike the low point of 1926, there are today 50 children under the age of 18 living on the Ridge. The total population of year-round residents is 147—about triple that of 1926.

In terms of numbers but not percentages, the elderly population is almost identical to that of a half century ago. There are 23 persons now who are age 60 or older, compared with 22 in 1926.

A particular characteristic of the Ridge has been the number of households headed by single people. There are 16 such units at present compared with 14 formerly. Twelve of the 16 are headed by women, mostly older widows. Twelve of the 16 households contain only one person.

Housing

Of the 69 dwelling structures on the Ridge, 12 are mobile homes, 9 of which have been placed there since 1967. Besides the increases in mobile homes, 11 new standard construction dwellings were built between 1926 and 1967, and 12 since then. In other words, the growth rate in the past ten years has exceeded that of the preceding 40 years.

An unusual aspect of housing on the Ridge is the continued presence of several vacant or dilapidated dwelling units. In 1926 there were ten such units and in 1976 there were six. In addition to the various classes of dwellings, there are two properties with barns only.

Farming

Using the census definition, we can identify 12 farms at present, only one of which can be considered commercial or a full-time farm. This is a dairy unit with approximately 50 cows. It contributes much to the agricultural quality of the area by making extensive use of what would otherwise be idle field land that is scattered throughout. Seven families keep a few chickens, and two keep pigs. Seven sheep and some beef cattle are kept on a second farm that has been used continually since settlement of the area.

Seventy percent of the households have family gardens and just under 50% cut varying amounts of wood for home use.

The total land holdings of the 69 units identified were estimated to be approximately 1 300 ha, over two-thirds of which are contained in eight holdings of 40 ha or more. Land still open is slightly in excess of 10% of the total acreage. All of this is either in small fields or essentially backyard areas. Hay and silage corn, a few Christmas trees and some timber and cord wood are the principal crops.

TABLE 1. Nute Ridge, changes in population, housing and land use, 1926-1976

Item	1926	1967	1976
		Numbers	
Total units inventoried	41	51	73
Non-residential	3	3	4
Residential	38	48	69
Vacant	10	3	6
Seasonal use only	2	10	14
Year-round	26	35	49
Housing Type			
Standard	38	45	57
Mobile home	NA[a]	3	12
Population—year-round	51	103	147
Age 18 or under	7	42	50
Age 60 and over	22	27	23
Widowed or single	14	17	14
Population—seasonal	NA	NA	40
Land use—farms[b]	17	12	12
Total ha[c]	NA	1 035	1 309
Ha open land[c]	NA	93	144
Livestock			
Horses	16	5	2
Cows	16	56	51
Other dairy or beef	3	13	17
Sheep	20	24	7
Pigs	1	4	6
Chickens	438	350	136
Households with garden	NA	NA	47
Households with home wood use	NA	NA	27
Households present during previous survey period	NA	9	26

[a]NA = data not available.
[b]Census definition.
[c]Increase in total ha and ha open due to increased units identified, not newly cleared land.

HALF-CENTURY OF CHANGE—SOME FINDINGS

The Ridge's population has increased in both year-round and seasonal residents. The proportion of seasonal residences is much greater now (22%) than it was a half-century earlier (7%). However, in the past ten years there has been no change in the relative proportion of year-round vs. seasonal housing. The growth that has taken place has been fundamentally for residential purposes. Farm numbers have declined from 60% to 19% of the active units on the Ridge. Their absolute numbers have decreased from 17 to 12.

Besides the shift toward residential use and the decline of subsistence agriculture, the other most significant change has been in population structure. A half-century ago, 43% of the total permanent population were 60 or older, and there were only seven persons 18 or under. Today, more than one-third of the present inhabitants are 18 or under. Persons 60 years of age or older now make up only

16% of the total population—an almost complete switch in age distribution pattern.

The Ridge population now, unlike in earlier times, contains many young families in the age range of 20 to 40. Employment, except for five self-employed persons, is entirely off the Ridge, and in several cases, out of state. Sixteen of the households are retirement families.

Today, the Ridge contains an almost totally non-homogeneous population. This population, unlike 50 years ago, is widely diversified in age and occupation, including unemployed, retired, labor, service, skilled trades and the professions, such as teaching and medicine. At least half a dozen households have members with post-graduate degrees, yet even more contain persons with less than a full grammar school education. With the exception of two or three teenagers, there is unanimous agreement that the Ridge is a great place to live. Only one household expressed a desire to leave. However, one gathers little sense of a tight-knit community in terms of any social organization. Few patterns of social visiting appear, except among related families or old timers. Membership in the Grange, the Nute Chapel, and the cemetery association is extremely limited as far as Ridge inhabitants go.

THE PAST IS PROLOGUE?

How do these present-day facts relate to Professor Woodworth's earlier conclusions?

1. There is some evidence that he was wrong in saying that young people shouldn't be expected to remain in the area as a matter of sentiment. Residents of all ages expressed strong feelings for the area and many noted past family connections in the general region if not specifically on the Ridge. One-fourth of all households had either past or present relatives on Nute Ridge.
2. As predicted earlier, much of the open field land has reverted to brush and woods.
3. The state of decline in population, in activity, and in quality of housing that disturbed Professor Woodworth 50 years ago has been reversed.
4. There has been a grouping of several farms into one as suggested. This was largely accomplished by use of leased rather than purchased land.
5. There is no evidence that some new form of centering influence has arisen to create a strong sense of community, at least in terms of social or political ties. The Chapel, with all its community facilities, has not fulfilled this kind of centering function as Professor Woodworth had hoped it might.

LOOKING AHEAD—SOME TENTATIVE CONCLUSIONS

In this summer of 1976, we, like our predecessor, also have been mulling over the data collected. These tell us a great deal about what is, but do not conveniently array themselves to either tell us why what is came to be, or to tell us what will be. We find that the best we can manage is the speculation that follows:

1. Relative isolation is no guarantee that growth will not occur, even when roads are rather minimal and no convenient shopping facilities are available.
2. Relatively inexpensive land or land available through family sources, plus lack of a strong building, zoning, or similar codes, tends to attract families of limited means, both retirement and seasonal, or people who can do at least some of their own home construction.
3. Despite the rural atmosphere and available space for home food production, such production is limited almost entirely to gardens. Also, of the 47 families with gardens, less than half either canned or froze food for off-season use. Seven families kept chickens, only two kept pigs, and one kept sheep. Twenty-seven families cut all or some wood for home use. Thus, rural living is not necessarily synonymous with independence from outside sources of either food or energy.
4. Despite unavailability of any shopping services and total lack of public transportation, a substantial number of elderly people and single person households prefer to live on the Ridge than in towns or villages. Perhaps retirement housing and rural transportation networks, while desirable, are not as essential as seen by social planners.
5. In almost 100% of the households, we found strong and positive identification with Nute Ridge as a place and way of life, even though social interaction with neighbors was limited. Apparently a sense of community can exist based upon identity with the physical location, without strong horizontal ties of social institutions and economic class.
6. In general, it seems possible to conclude that hill country life is alive and kicking, apparently due more to the physical combination of highway access and availability of land than to the presence of either strong social or economic structures. Our observations of Nute Ridge do not at this time suggest that new forms of community structures are emerging, or even are likely to emerge.
7. Despite the lack of identifiable social interaction, most households are aware of the activities of neighbors through an invisible information network. This characteristic is probably one of the more unique aspects of relative rural isolation, where the comings and goings of neighbors are fairly visible and when formal social interaction is lacking.

In any event, we conclude that Nute Ridge today is sailing a very different course than that plotted by Dr. Woodworth 50 years ago. What that course is remains as difficult to predict now as it was then.

The opinions of the residents of the Ridge agree on three points:

1. Growth is undesirable for the Ridge.
2. Growth will occur on the Ridge.
3. Where, what kind, how much and when growth will occur is unclear.

Finally, are there conclusions that might be drawn from a community developer's point of view?

Certainly the response could be yes. There needs to be a mechanism established which would facilitate social interaction among this group of inhabitants who, despite diverse backgrounds, share such a strong sense of place. In 1926, Dr. Woodworth expressed his hope that Nute Chapel, with its meeting rooms, library and kitchen, could perform this function.

Currently, several other suggestions come to mind. In 1967, we proposed some form of community project that could be shared by both seasonal and year-round inhabitants. One suggestion called for improvement of the Nute Spring as a wayside area. A very obvious current factor is the large number of young people under 18 years of age on the Ridge. No 4-H club exists, yet persons with the necessary time and skills for club leadership live there.

Another possibility lies with the rich human resources present, especially among some of the older residents. These resources include extensive educational backgrounds and skills, including such diverse occupations as logger, doctor, farmer, builder, bee keeper, skilled mechanic, sawer, engineer, greenhouse operator, nurse and organic gardener. These contain great potential for the establishment of a community self-learning project—the bringing together of neighbors who would like to learn something and neighbors who would like to teach something.

A final possibility—and perhaps the most realistic, given the long-time history of lack of individual leadership—is some form of group response to a proposed zoning ordinance. Recent unregulated growth in areas adjacent to the Nute Ridge have caused the Town of Milton Planning Board to conclude that the time has arrived when decisions must be made concerning types and location of growth. The ultimate result will be land use controls in the form of zoning.

The irony and the sadness of these suggestions lies in the fact that this small upland community, which for so long has resisted being "organized" internally, may be forced into interaction by external pressures. For example, it is quite likely that there will be no 4-H club unless the Cooperative Extension Service takes an aggressive role in organizing one. There is even less chance of a community self-learning project unless the School of Continuing Studies from the University of New Hampshire furnishes outside leadership (Fried, 1974). Finally, if a Ridge group response is organized to a zoning proposal (an external happening), the response will be reactive instead of proactive.

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40.
Hill Farming in Relation to Future Food Policies

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The impulse is almost overwhelming to open this paper by parrying the assigned title if not the focus of the entire conference. Hill farming in relation to future food policies, indeed! It would be equally appropriate to omit "hill" and speak of farming in relation to future food policies. Only in the last few years has farming in general been addressed in terms of food policies.

In the same vein we can consider the topic of another session this morning, titled, "Crop Production on Hill Lands: Has the Small Farmer Been Bypassed?" In recent months I have attended two international symposia in which the central theme was the bypassing of the small farmer everywhere—on flat lands and hill lands; cold lands and warm lands; wet lands and dry lands. In the northern hemisphere, the southern; the East and the West.[1]

But even as I suggest that in relation to food policies farming as a genus may fit better than hill farming as a species, I add quickly that in the agricultural history of recent decades hill farming has been treated disparagingly. In early days of the U.S., pioneer farmers preferred high land, in order to keep their horses' feet dry, if not their own, and to avoid malaria. Later, the preference reversed. Hill farming became déclassé. Ever since, in topographical snobbery level land has been regarded as high class, hill as low. Apart from progress in drainage that made lower terrain habitable, the introduction of tillage machines sped the shift in preference. Machines function best on flat land.

Moreover, as though to clinch the derogation of hill farming, we gradually came to believe that big machines on flat land, with associated technology, could produce enough food for all. By the mid-twentieth century surplus was feared. Hill land was therefore seen as superfluous.

Also contributing to low-caste status for hill land were notions about soil conservation. It was thought that sloping land erodes but flat land does not. A last source of hill land's obscurity was the new acclaim given livestock feeding, in displacement of ancient foraging. Much grazing of livestock takes place in hilly country.

[1]Symposia were the World Food Conference of 1976 held at Iowa State University, June 27–July 1, 1976; and the meeting of the International Association of Agricultural Economists, Nairobi, Kenya, July 27–August 4, 1976.

The major event of the 1970's that shocked agriculture worldwide and that extends to every productive acre on Earth was the tightening of food supplies. The world food situation was quickly labelled "crisis." International food conferences were called. Even in our country we lost our confidence that supply will always exceed demand, that the horn of plenty will stay full if not overflow. Paradoxically, we have become more self-conscious about our domestic food capability not because we are in any danger of running short of food for our people, nor even because we have committed ourselves to accept world responsibilities. Rather, the reason is that we export to food-short nations in order to get foreign exchange with which to buy the oil, chrome, tin and bauxite that we say we need; and we are fearful of not getting enough of them.

To decipher this perhaps cryptic language, the United States is so eager to export farm products because only in that way can we pay for the imported materials, petroleum above all, that we believe we must have. Literally, we are trading yellow corn for black oil, and thereby eating less meat, milk, and eggs in order to burn more diesel fuel and gasoline.

ESTIMATES OF THE WORLD FOOD SITUATION

This brief confession that U.S. worries about food production stem in part from our insistence on buying oil and other minerals does not invalidate the genuine and well-based apprehension about capacity for food production in the United States and all nations. But as we address the capacity question we find, unhappily, that concern is real but omens few. Events to date demonstrate not that food shortage is certain but that food abundance is uncertain. That is to say, the only honest appraisal is that we do not know what the future has in store. My own judgment is a bit negative, for reasons I will explain. But the only responsible starting point is the admission that evidence is inconclusive.

The historical record, nevertheless, is clear enough. During the 1960's agricultural production worldwide increased at a steady pace. It did so at about the same rate in the food-abundant and the food-short nations. Because the former had the slower population growth they enjoyed the greater increase in food per person. But even in food-short nations production outran population slightly and average diets improved.

The food-abundant nations got most of their food gains through technology, that is, by intensifying cultural practices. The food-short countries also profited from new technology, especially that of the Green Revolution, but they depended in part on adding new acreage to their land in cultivation.

In the 1970's the picture has modified. Everywhere the rate of increase in production has slowed. Food-short countries have been hard pressed even to keep up with population. African nations notably have been unable to do so; they have slipped backward in food per person.

ELEMENTS IN THE PROSPECTIVE FUTURE

Debates about prospects for the future turn on five issues: rate of technological advance; quantity and quality of new land; availability and cost of industrial inputs, notably nitrogen fertilizer; institutional restrictions; and that old friend or non-friend of agriculture, the weather. I will touch on each, though not in that order.

Perhaps most controversial of all is the state of affairs regarding cultural technology. Debates run the gamut of (alleged) absence of new scientific breakthroughs, cooler support to agricultural research, preoccupation with big farmers in humid areas to neglect of small farmers in drier places, and restraints imposed for purposes of environmental protection. There are grounds for some pessimism.

With regard to available new land, although impressive statistics can be quoted about how much good land on Spaceship Earth remains to be developed, this modest citizen begs to be allowed some skepticism. To be sure, some good land requires only clearing, draining and/or building access roads. But a more sober judgment is that most of the planet's good land has been put to productive use. That which remains is poorer.

As an economist I cannot appraise the dire predictions voiced by Professor Bryson at Wisconsin, Professor McQuigg at my school and other meteorologists about the world's weather. They see it as worsening. It would be anti-intellectual to reject their warnings summarily.

How important are environmental restrictions? They are confined to relatively few countries. For my part, I suspect that saturation of soil with some chemicals would eventually prove injurious in any case. Limiting their use for anti-pollution purposes may not be so important. This too is difficult to estimate accurately. Environmental rules may reduce output a little but my judgment is that the overall effect is not great.

Acts of man have always been as much an impediment to agriculture as Acts of God. Some governments still do not give enough support to agriculture, some tenure systems keep good land underutilized and some tax and tariff policies inhibit the best use of agricultural resources. The least to be said is that these are no worse now than in the past and may in fact be improving slowly.

The big unknown factor, in my judgment, is the terms of availability of industrial inputs to agriculture. In so-called developed countries such as the United States the technological revolution that has added so much to productivity has been built around those inputs. Most of them trace to the metals and petroleum. Nitrogen fertilizer is probably the most strategically crucial for the near term future. It is manufactured primarily through use of fossil fuel energy. The Green Revolution in other countries has relied mainly on access to the same industrial inputs.

It is self-evident that the world's supply of fossil fuels is being depleted. Although political changes such as collapse of OPEC could affect the immediate situation they cannot prevent eventual depletion. And even if OPEC should splinter, it would be replaced by a new group. Not least among sponsors would be the big U.S. companies for whom OPEC holds a shelter literally worth billions of dollars.

In the longer view other shortages also will affect agriculture—mineral nutrients, even iron ore.

Conceivably, national governments could take steps to protect the interests of agriculture in getting fuel, fertilizer and other industrial inputs. Only the richest nations could protect and subsidize liberally. Poorer ones simply would not be able to do it.

For this reason above all others I join the substantial number of scientists who believe that reduced availability of industrial resources will act as a retarding influence on agricultural productivity worldwide.

Having developed this argument, I reverse course and suggest that the validity of my overall appraisal—or anyone else's, for that matter—is relevant only in a special sense. Food policy for the future dare not be based, it seems to me, on the forecast offered by one's favorite seer. It must rest on uncertainty itself. Any wise nation, including ours, will prepare for the possibility of a shortfall in future food supply. If a shortage does not materialize, we will breathe easily and yet be pleased for our precaution. If it does come, our preparedness not only will relieve our anxiety but in some circumstances could save us.

THE "PRODUCTION ECONOMICS" OF HILL LAND

Manifestly, insofar as tighter supplies of industrial inputs put a crimp in our agricultural productivity, the vital role of all the world's land, including hill land, will be newly appreciated. This is axiomatic.

Of more specific meaning to hill agriculture is how the comparative position of hill land will be affected. If cheap industrial materials including farm

machinery helped to subordinate hill land in the past, will their growing costliness act to reinstate those portions of Earth having a vertical gradient?

This poses a question technically known as the production economics of hill versus level land. What is the responsiveness of various categories of land to mechanical cultivation, to fertilization, to use of chemicals?

Furthermore, insofar as hill lands are grazed, what is the production economics of forage versus concentrate systems of livestock production? This may be the more pertinent question. Countries such as the United States have gloried in converting much of their livestock and poultry industries to intensive feeding of concentrate feeds, often done mechanically in large establishments. Will higher priced industrial inputs act to dampen intensive feeding of concentrates? Will they give a boost to various forage programs including those based on hill land? In the United States during the 1970's to date the trend has been in that direction. The clearest instance is feeding of cattle, which is no longer so intensively based on concentrate feeds. The recent changes in U.S. grade standards for beef accommodate changed feeding patterns.

The hypothesis is that the trend to more costly industrial inputs in agriculture will on balance work to the comparative advantage of hill lands. The reinstatement of their status may be the more notable because they have been bypassed more than they should have been. Nevertheless, these are technical questions; they rest on the parameters of the (comparative) production economics of hill land. Speakers who follow me on this program will have more concrete observations to offer.

PROTECTING ALL PRODUCTIVE FARMLAND, INCLUDING HILLS

My last comment relates to social policy toward protecting farmland for agricultural use. Again, the principle applies equally to level land and hill land. In our vast United States, which closed its frontier only a half century ago, land has been regarded as so plentiful that it has been virtually treated as though it were eternally limitless. To some extent we have been the more profligate with regard to level land, not because it is more attractive for nonfarm uses but because it requires less grading to convert it to a highway, an industrial site or a suburban residential development. On the other hand, hill lands have had their own competitive claimants, particularly for recreation.

I have no idea whether we have been more successful in controlling erosion and otherwise conserving soil on hill lands or in flatter areas. My impression is that success has been mixed in both places.

If attentiveness to safeguarding our food supply leads to policies to safeguard our land base, heroic measures will be necessary. Once more, they are basically identical for all kinds of land. But, also as repetition, if our prevailing national attitude has been to subordinate hill country the greater trauma will be in restoring it to improved status. American citizens will readily fasten down Iowa silt loam to keep it from washing into the Mississippi River. They are less disposed to protect West Virginia's hillsides.

To end where we began, a food policy for the future dictates renewed respect for the land base for human survival—level land and hill land equally. But because hill land has been depreciated more in the past, it may be necessary to appreciate it more in the future.

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DISCUSSION

L. Bagley (West Virginia, USA). Would you expand somewhat on what you meant by balance in this situation? Also, you indicated that livestock production would switch back to forage.

Breimyer. Since I have taken some very strong stands, I was trying to be on guard to say, "Don't read me all the other way, either." We're going to continue to have feedlot feeding and the economics will govern, but policy comes in to some extent. For many years we paid an export subsidy on grain. If grains become surplus—even wheat, which can be fed—will we again subsidize exports? If we do we will restrain feeding to our livestock. There are a number of ways, most rather marginal and subtle, in which policy enters in.

Just before the oil embargo began, we were talking in the Midwest about actually air-conditioning confinement feeding of beef cattle. Fortunately, the higher price oil came in time to stop most of those projects in their tracks. That would be going the other way, you see, and I think that's going overboard in the way of stressing confinement feeding.

By balance I'm just saying we're not going to an entirely different kind of agriculture.

I think that economics and policy together will force our agriculture away from what it has been—row-crop, level-land, fertilizer-intensive. We will go to more mixed systems with more forage. In beef cattle, in Missouri at least, we have gone a little

more to "backgrounding" of our calves on forage and we aren't putting them on the concentrate feed quite as early. Now this is a change, you see. Not so many years ago we were putting calves in feed lots at 400 pounds for intensive grain feeding to market weight. Now the trend is toward backgrounding with more forage and putting them in at 700 pounds, maybe, and only offering intensive concentrate for the last 300 pounds. It's a marginal change but significant.

Another policy application would be if you were to have in this country a new period of surplus and low prices, and the question then would be, do you retire land and cut back production, which means that you cut back feed for livestock or do you accept somewhat lower prices but keep the feed flowing for livestock? So there are what I call marginal decisions that do relate to this matter of balance.

E. deVries (Pennsylvania, USA). I agree with your listing of the major factors that all lead into uncertainty. I would like to under-stress and over-stress another of your views. I think we are able to move in the direction of new technology, using microorganisms. The microorganisms have no body temperature to maintain and therefore are even more efficient than those of the ruminants and other animals and higher plants in many cases. So perhaps there is a new technology around the corner not only in the United States but in other parts of the world as well. And the second point has to do with environmental factors, soil destruction, etc. When you go to the tropics and you read the FAO report from a couple of weeks ago you will see that 250 million hectares have been lost in the last ten years. We discussed that two days ago—the question of soil destruction. It might be very costly to bring that land back into production or maybe it is lost for half a century until it would return to forest. On this second point I am less optimistic than you that we will find a natural balance by the forces within society without a tremendous international effort where again science, technology, institutional arrangements, and capital will have to go together. I have a feeling that it should be the concern of scientific circles in the northern part or in Australia and New Zealand, the more southern sector of the globe, to look more carefully at the tropics as a possibility and also as a danger.

E. Leng (Washington, USA). I'd like to get a three-way argument started between the forage crop and the crop production people and the economists. It has to do with your comment about nitrogen. The facts are that there are two pounds of elemental nitrogen in 100 pounds of wheat or similar figures from maize and other crops and you can't get away from it. I sensed from what Roy Hughes and other people from the Welch Plant Breeding Station and from Britain said, that much the same thing holds about grass. You can't really produce grass without nitrogen some way or another. Now in the face of this what are we going to do?

Breimyer. As to having to have nitrogen, yes; and in my prepared paper I have one line saying that in the wealthier nations such as the United States we can, if we want to, subsidize petroleum for agriculture. I should have put a footnote in—it isn't as easy as you might think because everyone else wants to get subsidized too. Second, many of the poor countries of the world can't do it as readily as we can because they don't have the money to do it with so it's still a constraint. As an economist I can argue with you a little. To some extent the nitrogen also builds the base with which you're converting sunlight. Some plant breeders think you can find germ plasm, which improves the ratio of conversion of sunlight for a given nitrogen input.

deVries. In Los Banos we have just discovered that with the right combination of blue algae and aeration we can produce with new rice varieties on well-irrigated land as much rice without any nitrogen fertilizer as you do with fertilizer.

F. Sineiro (Spain). It seems to me that with the legumes in the pasture we can release the pressure for nitrogen and concentrate on putting more nitrogen in the (other) crops. Also, if you use the alternative you can get a cash crop after several years of a pasture. For instance, if you put pasture in a rotation four or five years, and one year cash crop, you can get the cash crop with low level input of fertilizer nitrogen. My point is to concentrate more on the nitrogen for the other crops and to use as little as we can for pastures.

Breimyer. The main point I was trying to make, if my observations as an economist are at all reliable, is that we're going to have higher priced industrial inputs and particularly higher priced petroleum. I don't thing we've seen the peak yet. I don't think the higher prices have worked themselves through the system yet and I think there are still enough basic economic principles involved that we're going to have to make sure that we get more value out of these inputs in the future than the past. I think these realities change the cultural practices in agriculture worldwide.

42.
Economics of Hill and Mountain Farming in the United Kingdom

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Extensive pastoral systems dominate the farming of the hill and mountain regions of the United Kingdom and Western Europe. Difficult climatic conditions lead to short growing seasons and a consequent imbalance between the potential stock-carrying capacity in the summer and that of the long winter. Poorer soils, coupled with steep slopes, limit possibilities for cultivation and improvement of pastures, and, even where improvements are possible, these can be costly and may lead to a further widening of the difference between stock-carrying capacity in the summer and winter months unless forage conservation is increased or the grazing season extended.

In addition to the physical constraints, many of the farms in hill and mountain regions are too small in size of farm or size of business to provide an adequate livelihood by modern standards. In many regions the poor size structure, in some cases shortage of capital, and, in many other cases a natural conservatism, result in severe social and economic problems. The exodus of farmers and their families from hill and mountain regions, because of economic difficulties, often adds to the social problems, because of the growing per capita cost of providing essential services for a declining population.

Nevertheless in the UK and Western Europe the farming of the hills and mountains is generally closely linked with farming on adjacent lowland. Breeding and fattening livestock from hill farms are, to some extent, essential to the economy of many lowland farms. At the same time the need to farm the hills and mountains, and to maintain an economically viable population in those areas, can be important to increase national self-sufficiency for food and to provide the essential services and amenities for associated industries and activities such as forestry, water supplies, community leisure pursuits and tourism.

HILL FARMING IN THE UNITED KINGDOM

Most hill farms in the UK consist of a relatively small area of enclosed cultivated land surrounded by a much larger area of rough grazing which may or may not be in the process of some improvement. On the other hand, upland farms are those operating under more favorable conditions of soil and climate, compared with hill farms, and where the ratio of enclosed cultivated land to rough grazing is much more favorable. Nevertheless, these upland farms operate often under distinct disadvantages of soil and climate compared with most lowland farms. A high proportion of the agricultural land classified as rough grazing in the UK in Table 1 is devoted to hill farming and it has been estimated that out of a total of 18.7 million ha in the UK, nearly 8 million ha is used by hill and upland farming (N.E.D.O. 1973a). Approximately 26 000 full-time farming units, about one seventh of all such holdings in the UK can be considered to fall into the hill and upland farming groups. In addition, there are some 35 000 part-time farming units in hill and upland areas, amounting to roughly one fifth of all UK part-time holdings. About one ninth of the total agricultural labor force is to be found on hill and upland farms, including some 25 000 full-time and regular part-time paid workers, as well as farmers and unpaid family workers.

TABLE 1. Distribution of agriculture in the United Kingdom (million ha)

Type	England and Wales	Scotland	N. Ireland	United Kingdom
Arable land (including temporary grass)	5.6	1.3	0.3	7.2
Permanent grass	4.0	0.4	0.6	4.9
Rough grazing	1.8	4.5	0.2	6.6
Totals	11.4	6.2	1.1	18.7

Sources: Ministry of Agriculture, Fisheries and Food (1975); Agricultural Statistics 1973, H.M.S.O., London; Department of Agriculture for Scotland (1975); Agricultural Statistics 1973, H.M.S.O., Edinburgh.

These hill and upland farms are estimated to produce nearly 7% of the total gross output of UK agriculture. This includes about 47% of the total sheep and wool output and 25% of cattle output (excluding milk). Hill farming in the UK thus provides a significant proportion of the grazing livestock output, partly as fat animals, but mainly as store stock for fattening on lowland farms. In addition,

hill farms transfer annually to lowland farms large numbers of breeding stock in the form of culled ewes from hill sheep flocks or young breeding cattle. The stratification of the sheep industry between hill, upland and lowland farms in the UK is often claimed as a major justification for maintaining economically viable farming units in the hills. This stratification rests on a foundation of pure-bred sheep dominated by the hill breeds which constitute some 57% of the total breeding ewe population. Table 2 indicates the extent to which hill sheep breeds, either pure or cross-bred, contribute to the output of lamb carcass meat (M.L.C. 1972).

TABLE 2. Composition of the sheep industry in the United Kingdom

Breed Type	No. of Ewes as a Percentage of Total Breeding Flock	Estimated Output of Lamb Carcass Meat as a Percentage of Total Annual Output
Hill breeds—pure-bred	38	18
Hill breeds—cross-bred	19	16
Other breeds—pure-bred	4	6
Other breeds—cross-bred	10	11
First cross ewes—cross-bred	20	33
Other cross-bred ewes—cross-bred	9	16

Source: Meat and Livestock Commission (1972) Sheep Improvement—Scientific Study Group Report. M.L.C., Bletchley, England.

HILL FARM STRUCTURE

Too many small holdings incapable of providing an adequate income by modern standards has long been a feature of hill farming in the UK. Tables 3A and 3B show the position for size structure in terms of standard man-day requirements for full-time farms. In addition, there are many thousands of part-time holdings in England, Wales and Scotland where the labor requirement is very much less than 1 man unit (275 man-days). Nevertheless it is clear that many occupiers of small units are prepared to continue farming for a low material income. Surveys have shown that the average age of occupiers of these smaller units is considerably higher than for farmers generally in the UK. Sons and daughters are less willing to accept these lower incomes so it may be that time alone will provide some solution to this structural problem.

The strong demand for extra land by some of the younger members of the hill farming community is an indication of the recognition of the need to increase the size of units. But land prices remain high (reflecting the demand) and often out of reach of those who wish to expand. In many cases the interest and repayment charges on loans for land purchase can impose an intolerable burden on many small hill farm businesses attempting to grow in size.

Government Support for Hill Farming

The contribution of hill and upland farming in the UK cannot be measured in terms of gross output alone. Account must be taken of the cost of achieving this, especially the support from public funds. In 1974–75 it was estimated that hill and upland farmers in the UK received special production grants amounting to some £37 million out of a total of £229 million in public expenditure on price guarantees and grants to UK agriculture. In addition, hill farmers received a proportion of the support for capital improvements as well as subsidy on reared beef calves and price guarantees on fat sheep and cattle. The importance of these grants and subsidies for hill farming is indicated in Table 4 where a comparison is made between hill and lowland farming in Great Britain in terms of the contribution that grants and subsidies make to gross output and net income.

Table 4 shows that, for Great Britain as a whole, deficiency payments, production and all other grants amounted to 30% of net farm income, whereas for the hill and upland areas alone such payments and grants represented 11% of net farm income. For lowland farming in Britain the contribution amounted to only 24% of net farm income. The importance of financial support for hill and upland farming is further illustrated in Table 5 where the contribution that such support has made to different types of farming in the north of Scotland is shown. Here hill and upland farmers received exchequer support amounting to 36 to 38% of net farm income in 1972–73, a year when economic conditions were good and as much as 89 to 111% in a poor year. The crofts in Group VII in the Table represent an interesting type of hill and upland farming. There are over 20 000 of these small semi-subsistence type of farms, mostly in the west and north of Scotland. They are covered by special legislation and have a very poor size and business structure, and many are part-time holdings.

Hill Livestock Compensatory Allowances

Up to 1975-76 the special production grants for hill farming consisted of hill beef cow and hill sheep subsidies. In 1975 these amounted to £24.50 per cow (including £5.75 winter keep supplement) and

TABLE 3A. Distribution of hill and upland farm types in Great Britain, by size of business

Size of Business (Standard Man-days)	England and Wales, 1970 Full-time Farms				Scotland, 1971 Full-time Farms		
	England		Wales				
	L.M.S.[a]	L.C.S.[b]	L.M.S.[a]	L.C.S.[b]	Hill Sheep	Upland	Rearing With Arable
250–274	c	c	c	c	49	284	181
275–599	328	2 111	1 018	3 300	546	2 438	1 731
600–1 199	333	1 405	677	1 751	407	1 708	1 082
1 200–1 799	86	396	130	259	147	475	278
1 800 and over	28	216	50	63	64	274	194
Totals	775	4 128	1 875	5 373	1 213	5 179	3 466

[a]Livestock, mainly sheep.
[b]Livestock, cattle and sheep.
[c]Not separately recorded.
Sources: Ministry of Agriculture, Fisheries and Food (1972). Agricultural Census 1970. H.M.S.O. London.
Department of Agriculture for Scotland (1973). Agricultural Census 1971. H.M.S.O. Edinburgh.

TABLE 3B. Distribution of farming units receiving hill farming subsidies in Northern Ireland, by size of business, 1970

Size of Business (Standard Man-days)	Number of Farm Units	Percentage of All Farm Units Over 50 S.M.D.S. in N. Ireland
Under 50	1 920	—
50–199	5 280	29.4
200–449	3 000	25.3
450–599	620	21.3
600 and over	340	7.9
Total of all sizes 50 S.M.D.S. and over	9 240	24.9

Source: Ministry of Agriculture for Northern Ireland (1971). Agricultural Census 1970—5% sample. H.M.S.O. Belfast.

£3.60 or £2.85 per ewe, depending on breed, for all beef herds or sheep flocks kept on eligible land. These grants were subject to maximum stocking ratios of one cow to 1.6 ha and 6.2 ewes to every ha of eligible land. Farmers may have stocked more heavily than this but would be paid only up to the maximum rates allowed. This qualification was introduced to avoid over-grazing which at one time was said to result from the application of such subsidy payments.

In 1976 the Hill Livestock Compensatory Allowances Regulations were introduced to implement Directive 75/268 of the Council of the European Economic Community (E.E.C.) which is designed to assist farmers in the less favored farming areas of the E.E.C. These regulations took the place of previous special support schemes and to qualify a farmer must occupy at least 3 ha of eligible land. The compensatory allowances at the present time amount to £29 per head for breeding cows and £3.60 or £2.85 per ewe, depending on breed. In any year the overall payment to any person (not farm) is

TABLE 4. Grants and subsidies to agriculture in hill and lowland Britain, 1970–71 (million pounds)

Item	Hill Farming G. Britain	Lowland Farming G. Britain	Total G. Britain
Livestock grants	28.5	24.9	53.4
Other production grants	3.7	37.3	41.0
Fatstock deficiency payments	12.3	33.5	45.8
Wool subsidies	2.4	3.2	5.6
Cereal deficiency payments	1.1	27.9	29.0
Capital grants	1.8	35.1	36.9
Estimated net income	43.0	540.0	583.0
Livestock production grants as a percentage of net income	66	5	9
Livestock production grants, and other grants, subsidies and deficiency payments as a percentage of net income	111	24	30
Capital grants as a percentage of net income	4.1	6.5	6.4

Source: National Economic Development Office (1973b) Evaluation of the Economic Significance of Agriculture in the Hills and Uplands of Great Britain. N.E.D.O. London.

TABLE 5. Exchequer support per farm, and as a percentage of net farm income; identical sample, 1970–71 to 1972–73, for the north of Scotland

Farm Type Groups	No. of Farms	1970–71 Support (Pounds)	1970–71 % of Net Farm Incomes	1971–72 Support (Pounds)	1971–72 % of Net Farm Incomes	1972–73 Support (Pounds)	1972–73 % of Net Farm Incomes
I. Hill farms	18	1 613	111	1 865	54	1 935	36
II. Upland rearing farms	16	2 012	89	2 307	51	2 400	38
III. Mixed farms (Cattle & sheep)	105	1 193	56	1 513	45	1 445	23
IV. Mixed farms (Arable)	29	916	33	1 761	42	1 040	12
V. Mixed farms (Intensive, pigs & poultry)	26	1 329	18	2 172	24	1 424	9
VI. Dairy farms	19	358	10	719	10	278	3
VII. Crofts	17	646	78	726	61	778	37
All farms in sample	230	1 158	41	1 578	36	1 351	18

Source: North of Scotland College of Agriculture (1974), Farm Incomes in the North of Scotland 1970–71 to 1972–73. Aberdeen.

subject to a maximum of £50 for each ha of eligible land.

Hill farmers are eligible also for special rate payments under the Farm and Horticultural Development Scheme which is designed to help all farmers whose incomes are below the national average for non-agricultural industry, to improve their holdings and achieve a comparable income. Grants to hill farmers may amount to 30% of the cost of erecting buildings, 40% for forage silos, 50% for road works, water supplies, fencing and land clearance, as well as 15% of the cost of any extra livestock needed to achieve the approved plan. Holdings eligible for such capital grants must have a present earned income not exceeding £3,000 per labor unit. Obviously any eligible holding must be capable of achieving the minimum income standard after improvement, and for some small units this could be one of the major problems. Having the necessary capital resources to implement the plan, even after the allowances are paid, may present problems but the scheme does include "Guidance Premium Payments"[1] of £54 per ha over three years on the land necessary to support the cattle and sheep suitable for meat production. There is a maximum of 100 ha on which such a premium will be paid (M.A.F.F. 1976).

All in all, therefore, it seems that hill farmers in the UK are generously treated in terms of government support. This support recognizes the low incomes from hill farming and it seems that more and more emphasis in the future in these support schemes is to be placed on providing incentives to improve the output of the holdings. The question is, what kind of return in increasing food output and reducing costs can be expected from this national and E.E.C. investment in hill land? There can be little doubt that many relatively small hill farms capable of sustaining a one-man work unit or more will be kept in business where otherwise rising costs would make it difficult to continue operating. How far such a policy will improve the general structure of hill farms, or will maintain a structure that is already out-dated by modern standards, is difficult to foresee.

The Economy of the Hill and Upland Farm

Profitability in hill and upland farming in the UK varies from region to region according to the severity of climate and the quality of the grazings. Some indication of the levels of output and incomes achieved in relation to costs incurred can be seen in Tables 6 and 7 where the results for hill and upland farms are compared for 1973–74 and 1974–75. The figures show considerable between year variation in net farm income, reflecting differences in weather conditions and prices of products between the years. In 1974–75, lack of conserved winter feed forced many hill farmers to sell their cattle in the autumn months. This contributed to an already falling market for store cattle because of lower prices for beef.

On the upland farms that have a higher proportion of better land to rough grazings, the winter feed supply situation was not so acute and farmers were less obliged to sell cattle in a falling market. As a result, the net farm incomes on the upland farms showed little variation over the two years. These results emphasize the importance of weather conditions and the dependence of the hill farms on prices received for their products. If lowland farmers, who

[1]Given to enable farmers to provide the necessary working capital to carry out an approved plan of farm improvement.

TABLE 6. Average cropping and stocking, outputs, inputs, net income, and performance measures by size of business, 1973–74 and 1974–75, for hill sheep farms, Scotland

Size of Business	275–599 SMD[a]		600–1 199 SMD		1 200 and over SMD	
Year	73–74	74–75	73–74	74–75	73–74	74–75
No. of farms	20		31		67	
Av. size of business (SMD)	460		851		1 754	
			Ha			
Total area	702	700	1 451	1 448	1 924	1 892
Rough grazing	675	673	1 421	1 416	1 841	1 809
			No.			
Breeding cows	15	15	27	27	59	64
Breeding ewes	443	490	954	965	1 783	1 790
			£			
Total gross output	8 368	6 868	14 439	12 344	29 402	28 812
Total input[b]	3 864	4 867	8 691	9 853	19 589	23 418
Net farm income	4 504	2 001	5 748	2 491	9 813	5 394
Performance Measures						
G.O/£100 input[c]	165	103	159	110	147	119
G.O/£100 lab.[c]	435	278	416	294	459	365
G.O/£100 lab.[c] and mach.	327	212	327	223	321	254

[a]Standard man-days.
[b]Excluding labor of farmer and wife.
[c]Including labor of farmer and wife.
Source: Department of Agriculture for Scotland (1976). Scottish Agricultural Economics 26. H.M.S.O. Edinburgh.

TABLE 7. Average cropping and stocking, outputs, inputs, net income and performance measures by size of business, 1973–74 and 1974–75, for upland farms, Scotland

Size of Business	275–599 SMD		600–1 199 SMD		1 200 and over (SMD)	
Year	73–74	74–75	73–74	74–75	73–74	74–75
No. of farms	35		46		20	
Av. size of business (SMD)	458		848		2 211	
			Ha			
Total area	137	139	240	241	1 367	1 236
Rough grazing	97	98	168	166	1 175	1 042
			No.			
Breeding cows	29	32	52	55	104	109
Breeding ewes	101	105	252	254	631	605
			£			
Total gross output	7 762	9 018	14 477	15 755	42 021	48 746
Total input[a]	4 898	6 174	9 613	11 181	31 024	39 153
Net farm income	2 864	2 844	4 864	4 574	10 997	9 613
Performance Measures						
G.O/£100 input[b]	129	116	136	124	140	125
G.O/£100 lab.[b]	432	352	465	396	517	467
G.O/£100 lab.[b] and mach.	265	226	293	256	319	282

[a]Excluding labor of farmer and wife.
[b]Including labor of farmer and wife.
Source: Department of Agriculture for Scotland (1976). Scottish Agricultural Economics 26. H.M.S.O. Edinburgh.

buy the unfinished products of hill farms, lack the necessary feed resources to fatten the stock or face falling prices in the meat market, then the consequences for the hill farmer can be severe. Levels of net farm income in the past, even in relatively good years, have often provided a modest return to the farmer and his family for their labor, their management and the investment of capital. Government support is an essential part of economic viability.

In 1976, however, there are many indications of a growing confidence in the future of hill farming in the UK. Higher prices for cattle and sheep in addition to fairly generous production and improvement grants are now operating and, although costs have increased, the degree of self-sufficiency on hill farms has protected them from the worst effects of rising costs. Many hill farmers are now taking advantage of the improvement grants to improve the stock-carrying capacity of their farms and to raise the level of nutrition of their cattle and sheep. By improving their grazings hill farmers now find that they can sell a higher proportion of their lambs as finished fat lambs and so become less dependent on the ups and downs of the store livestock market. The new E.E.C. regulations governing aid to less favored areas are likely to instil further growing confidence in the industry and help to raise incomes.

Perhaps a more orderly system of marketing of cattle and sheep from hill farms could help to reduce the wide fluctuations in prices that hill farmers received for their products. At present most stock coming from hill farms are sold in auction markets. This system may have worked satisfactorily in the past but it has many disadvantages. Wide variations in prices from market to market, the selling of livestock in relatively small lots and the lack of direct contact between the seller and the ultimate user of the stock are some of these. In recent years there has been a growing development of cooperation between producers in the selling of their stock. This has the advantage of offering larger batches of better graded stock for sale and the possibility of direct contact between the cooperative and the ultimate users. Grants are available for setting up such producer cooperatives and it is hoped that such a development will lead to less price variation and more orderly marketing.

The Economics of Hill Land Improvement

Increased stocking rates and improved nutrition are the key factors in raising output on hill farms. The increased incomes that could result from these improvements hinge on the relationship between the value of the extra output obtained and the costs of achieving the improvements. The large areas of relatively unimproved hill land in the UK have inspired many people over the years to investigate ways of improving the pastures and to consider the possible impact of such improvements on the fortunes of hill farmers.

In the past much of the land improved has been improved through plowing and reseeding and in many cases this land has been of a "kinder" nature than the bulk of rough grazings on hill farms. Often this has resulted in quite spectacular improvements in stock-carrying capacity and nutrition. Today the costs of such operations have risen very sharply and greater emphasis is now being given to improving some of the poorer land by surface treatment, including reseeding and fertilizer application. There are many examples of this form of improvement but perhaps the results obtained at the Ministry of Agriculture's Experimental Husbandry Farm (E.H.F.) in Mid-Wales gives some indication of the benefits and costs involved (M.A.F.F. 1975). The Pwllpeiran E.H.F. is situated about 14 miles from the Mid-Wales coast at an altitude ranging from 265 to 625 m. The prevailing southwest winds bring an annual rainfall of between 1 780 mm and 2 540 mm on the mountain grazings. These grazings lie on blanket peat interspersed with drier hills of thin shale. Improvement has been by surface treatment at a cost which could amount to over £173 per ha at today's prices.

Improving about 121 ha out of a total of 648 ha has resulted in a marked improvement in stocking rate for breeding cows and ewes, an increased percentage of lambs weaned per ewe and better weaned weights of lambs. Total capital outlay has been of the order of £40,000 net of grant, and includes capital invested in the work of improvement, as well as the extra livestock and equipment. On a discounted basis it is estimated that internal rate of return on capital invested will be about 33% over a period of ten years. One of the problems of this kind of investment is that it is not until the fourth or fifth year from the start of improvement that the full cash benefits will be received and cash flows become positive.

The Pwllpeiran scheme would not have been possible without cooperation between farming and forestry. Access to carry out the improvements was a big problem and this was overcome by the sale of land for forestry with the agreed provision of an access road. Perhaps a lot more could be done in hill areas if farming and forestry cooperated for mutual benefit. Too often farming and forestry in hill areas have been in direct competition without attempting to plan land use for both purposes for mutual benefit.

Tax considerations may have a marked impact in the real costs of improvement. Where incomes from the hill farm are already high, and thus, the marginal tax rate is at a higher level, then a lot of the cost of borrowing capital for improvement can be offset against tax. For obvious reasons it is

likely to be the very much larger units, with higher taxable incomes, that are likely to benefit in this way. On the small hill farm, making little in the way of taxable income, no such benefit is possible.

Economic success in hill farming calls for high technical competence and considerable management skill. It has been suggested that the management skills required for successful hill farming are more than those needed for the same level of competence in lowland farming (Allen, 1973). As long as farms in hill areas remain relatively small as businesses the financial incentive is often insufficient to attract and retain the required skill in management. To achieve adequate returns from the investment of large sums in improvements on the hill farm demands this kind of management expertise often lacking on a high proportion of such farms. A report on "Manpower and Training Needs in Welsh Hill Farming" (Lees and Colyer, 1973) showed that only about 8% of hill farmers had received any formal agricultural education and that 85% of the work force were members of farming families. Little interest was shown in management training and matters related to marketing and trading policy.

Socio-Economic Aspects of Hill Farming

Changing the structure of hill farming in the UK so that fewer but much larger units remain would seem to be a satisfactory solution to some of the economic problems of this kind of farming. Economies of scale could result in a better return on investment for the improvement of forage production, greater efficiency in the use of modern machinery and fixed equipment and the need for a smaller work force. Such a move, if it were possible, would lead to an even more accelerated rate of depopulation of hill areas with consequential social problems and the difficulty of maintaining essential services to remaining communities.

Past and present government support for hill farming reflects the desire to maintain a stable and economically viable human population in the hills. Nevertheless, it seems that fewer of the smaller units will remain and that modern methods of farming will require fewer workers on all sizes of units. In many cases alternative employment opportunities are limited. At the present time some part-time farmers assist on larger units or do contract work in sheep shearing and land improvement.

Forestry and water conservation services can provide useful full- or part-time employment but the development of further job and income opportunities outside agriculture is required. This would seem to be important to stem the flow of young people from hill areas.

In recent years much attention has been paid to the conservation of natural resources. With increased leisure time for the community as a whole the use of hill and mountain regions for amenity purposes and tourism has grown. These leisure industries can provide jobs and opportunities for farmers to add to their income, but the absence of proper national or regional planning can result in undesirable development which often destroys the very amenity which it is hoped to preserve and exploit. Many farmers in hill areas now cater for tourism by providing accommodation or camping sites. While it is unlikely that such development will do more than slow down slightly the flow of population from the hills, it will certainly help to improve social and economic conditions.

HILL AND MOUNTAIN FARMING IN THE ALPINE REGIONS OF WESTERN EUROPE

Ranging through Austria into Switzerland, Italy and France, the alpine farming of Western Europe presents many contrasts and similarities with hill farming in the UK. The contrasts are mostly in the physical conditions and methods of farming, whereas the similarities are related to economic and social problems. The whole alpine region is too large to deal with in a paper of this kind but the farming of the mountain regions of Switzerland illustrates most of the difficulties of attempting to maintain economically viable farming systems in such conditions without creating intolerable social problems.

Mountain Farming in Switzerland

The mountain regions of Switzerland cover about 65% of the total land area, contain approximately 13% of the population and nearly one third of the farms (S.A.P.A., 1972). Present policy towards mountain farming in Switzerland is very much affected by national economic and social considerations. The two main factors here are the concept of self-sufficiency for food and the need and desire to maintain an active and economically viable population in the mountains to promote the orderly use of land and a proper balance between the rural and urban populations.

For historic reasons Switzerland attaches great importance to self-sufficiency for food. Past experience and the concept of political and economic neutrality have resulted in the present strategic plan whereby the agriculture of the country must be so arranged that, in an emergency, self-sufficiency for food, on a restricted diet, could be reached within two years. National policy, therefore, demands and insures that the whole of agriculture, including mountain farming, be maintained in a state to achieve the strategic plan should such an emergency arise. This means maintaining forms and methods of agricultural production in mountain regions which, on the face of it, might seem unduly expensive in purely economic terms.

The Swiss nation has a very strong emotional attraction to the mountains. Their national independence springs from the protection of the mountains, and most of the population have very close family ties with mountain farming. Today, the wealth of the country depends on intensive chemical and engineering industry and on financial transactions, and this has resulted in a steady flow of population from mountain regions to industrial urban centers. This has caused increasing concern because of its effect on the general way of life and on land use in the mountains. National policy attempts to promote the orderly use of land and population movement. This policy recognizes the importance of maintaining satisfactory standards of farming in mountain regions so that the mountains remain attractive to the community as a whole and, perhaps of greater importance, to the tourist industry which brings in so much foreign currency to aid the national economy.

The Problems of Alpine Farming

Physical conditions of altitude and its effect on the growing season, exposure, especially on north facing slopes, high rainfall and difficult conditions for cultivation, limit opportunities for agricultural production on alpine farms. Nevertheless, environmental conditions offer some advantages when compared with hill farming in the UK. At high altitude in the Alps the growing season is short but the very quick rise in temperature in the spring produces forage of a quantity and quality not matched by that found on hill farms in the UK. Undoubtedly methods of forage production and utilization on alpine farms, with the policy of using every available area for grass conservation, have a distinct bearing on this. At the same time, labor input is high on alpine farms compared with hill farms in the UK and mountain farmers in Switzerland and in other areas of alpine farming have a wide range of small machines adapted specially to the systems of farming and the difficulties of operation on steep slopes.

The structure of mountain farms in Switzerland is similar to that of most alpine farming regions in Western Europe. It is dominated by two characteristics. First, the numerical importance of many relatively small farms; a recent survey in Switzerland showed an average farm size of about 18 ha with a high proportion in the 5 to 10 ha group. Second, the dispersed nature of many holdings, partly due to the fact that the mountain farms may consist of several small areas of land located at different heights and partly because in many regions farmsteads may be situated in the village and the land parcelled out in fragmented units. In some cases the mountain grazing may be held in farmer cooperatives and used by the members in common. In recent years there has been a move towards the restructuring and consolidation of fragmented holdings.

Milk production for cheese and butter making is the main enterprise on most mountain farms in Switzerland but cattle rearing for sale to lowland farms is an associated important enterprise. Sheep production is relatively unimportant except in isolated regions. In the winter the cattle are housed in main farmstead buildings and during the summer they are grazed at increasing height as the season progresses. The highest pastures may entail the movement of farmer, family and cattle to summer units where cheese may be produced to transport to market at the end of the production season. Where these high grazings are held in common then each member of the cooperative will be allowed to send a certain number of cows for the whole summer season and production and processing will be undertaken by contract.

The Economy of Alpine Farming

In general a mountain farm in Switzerland provides only about 60 to 70% of the lowland farm income. That this is due to a lower level of production rather than size of unit is shown in Table 8 where average economic statistics for mountain farms are compared with those for lowland farms of similar size. Lower intensity of farming system and stocking on the mountain farm, coupled with reduced capital investment, are the main contributing factors. These lower incomes for mountain farmers occur despite relatively more generous support for the mountain farmer compared with his lowland counterpart.

Support for Mountain Farming in Switzerland

There is general support for farming in Switzerland through price support, production grants, capital investment grants and a system of support based on labor income parity with other industries. This support is part of government policy concerned with self-sufficiency and the maintenance of a strong rural sector of the population. Swiss mountain farming has always been encouraged by various promotional measures. Some of these apply to mountain farms only, while others are more general in scope but provide better conditions or higher subsidies for mountain farms compared to those elsewhere.

Grants and cheap credit for structural improvement have been provided where 85% of cost of structural improvements is given compared with 75% on lowland farms. Cheap credit schemes, repayable within ten years are based on plans submitted by the farmer with assistance from extension workers. Building grants of 65% on mountain farms assist in overcoming the extra cost of erecting farm buildings under such conditions and recognize the need to build more expensively so that such build-

TABLE 8. Mountain farms compared with lowland farms of similar size and system of farming in Switzerland in 1975

Item	Av. for Lowland Farms[a]	Av. for Mountain Farms[b]	Mountain Farms as a % of Lowland Farms
Agricultural land per Farm (ha)	17.7	17.5	98.6
Agricultural land per labor unit (ha)	8.0	10.3	129.6
Grassland per cattle unit (ha)	0.6	0.9	154.6
Milk yield per cow (kg)	4151	3685	88.8
Capital investment per ha agricultural land (Fr)	15603	11308	72.5
Farm income per ha (Fr)	2554	1720	67.3
Total income per farm (Fr)	45298	32034	70.7

[a]Lowland farms in survey = 715.
[b]Mountain farms in survey = 206.
Source: S.A.P.A. (1975) Farm Accounts, 1974. Swiss Assn. for the Promotion of the Extension Service in Agriculture, Küsnacht, 8703 Erlenbach, Switzerland.

ings fit into the landscape without detriment to amenity factors (Popp, 1975).

Direct income payments include a price support scheme for breeding cattle, especially for export, premiums on livestock for slaughter and for certain arable crops grown in mountain regions. Milk production, so important in mountain regions, suffers from an oversupply in relation to market requirements and, in order to control this, farmers are encouraged to change over to beef breeding herds by the payment of an annual premium per head on beef cattle. However, the attraction of the regular cash income from milk, coupled with a fairly generous milk price, reduces the attractiveness of beef production.

Some special measures to support mountain farming aim mainly at reducing costs. In general, the mountain farmer pays only about 65% of the normal purchase price for farm machinery. Support for mountain farmers in Switzerland is costly and is always an internal political issue. But so long as the national economy can meet the cost there seems to be a majority of the general community in favor of helping the mountain farmer.

Socio-Economic Aspects of Swiss Mountain Farming

Maintaining the natural attractiveness of alpine regions demands an active system of farming involving the regular grazing and conservation of forage on alpine pastures. The probability is that only systems involving cattle production can satisfy this need. It is said by mountain farmers and agricultural advisers that a possible alternative, sheep production, would lead to erosion and a deterioration of the pastures. The implications are clear and expensive. Maintaining cattle production systems and the village farming infrastructure means relatively small farms given generous national support.

For a country such as Switzerland, or indeed any other alpine region of Western Europe, this kind of support has a high cost, but, at the same time, it may provide important economic and social benefits. Tourism is the third most important industry in Switzerland (behind electronic equipment and chemicals and ahead of watchmaking and textiles) (Poore, 1975). In such circumstances no country can afford to ignore the conservation of its main tourist amenity. If we add to this the less definable benefits of the conservation of natural resources, the maintenance of a "way of life," including a planned system of population dispersal, then perhaps the cost of maintaining economically attractive farming systems in alpine regions may seem small.

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DISCUSSION

G. Jung (Pennsylvania, USA). You mentioned that you were subsidizing the small farmer in Great Britain and that most of these individuals needed more technology or they do not have management skill. I'd like to know whether there is any scheme that is routinely used when the small farmers are being subsidized for fencing, additional cattle, etc., to help them with the new technology, to give them additional training or anything of that sort. Is this routinely done or do you just let the farmer fare as best he can?

Pearce. In fact, the support is really given to all sizes of farms. Of course for the capital grants often the small farmer would benefit because of his income, his income per labor unit may well be small enough to allow him to qualify. Yes, in fact, assistance is given in devising plans, first of all, making up the plan which is the necessary part of the qualification for this particular grant. He will get help from his advisory officer of the Agricultural Development and Advisory Services and National Service in the region of the UK. But of course there is a limit to the amount of time these advisors can devote to individual farms. They may start them off by giving them help in devising the plan and perhaps putting them on the right line but beyond that, it's often difficult, I think, because of numbers of claimants involved for the individual advisory officer to keep in touch all the time with the progress being made by each farmer who is receiving assistance. And I'm afraid sometimes that unless the farmer himself makes continual demands on the service then he may not get as much help as he might need. In fact, the people that perhaps need the most help don't always call for it.

H. Silver (North Carolina, USA). You're presentation on hill farming has all been based on livestock farming. Is it not profitable or is there no encouragement for a horticultural crop which would use a greater number of hours of human input?

Pearce. I don't think the weather conditions in the UK on the kind of land that we're talking about are such that one could contemplate any horticulture croppings.

E. Wiegandt (Michigan USA, and Geneva, Switzerland). I would like to add a comment on that last question for Switzerland. One of the efforts being made by the Swiss Government is to produce labor intensive horticultural crops in certain areas of the Alps because they are labor intensive, and since you can't mechanize in the high Alps, you might as well introduce crops where the differential between labor inputs in the plains and in the mountains wouldn't make much difference.

Pearce. The climatic conditions in the Swiss Alps are very different from those of Scotland, Wales or Northern England in that the temperature rise in the spring is much more rapid than it is in the UK. This makes for much better growing conditions. One of the things I have seen in Switzerland is the growing of strawberries at different heights. You'll find a farmer growing strawberries at different heights simply to capture the markets in a succession and it's very useful because when the people down in the lowlands have harvested their strawberries he's still growing strawberries up to about 6 000 feet and corners the market. But even there, I imagine, there must be relatively few opportunities apart from very favorable valley areas perhaps in the west and the French sector.

43.
Economic Evaluation of Food Crop Production on Hillsides—The Caribbean Experience

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This paper is concerned with an economic analysis of food crop production on hillsides in the English-speaking countries of the Caribbean. These countries are commonly referred to as the Commonwealth Caribbean and constitute fourteen member states including the mainland territories of Belize and Guyana on the Central and South American continent, respectively.[1] Total population is estimated at five million people. Both Guyana and Belize are relatively flat and so very little food crop production occurs there on hillsides. In fact, many of the hilly lands are inaccessible, especially those in Guyana. As a result, most of the discussion will exclude these countries, except when market considerations are emphasized. The information is presented in the next five sections.

Analysis of the data presented in the paper was constrained by a lack of a uniform data base on a Caribbean-wide basis. Considerable variation in the quality and availability of the data on domestic agriculture prevented a much more rigorous analysis of the problem on a comparative basis. However, the data problem is not unique to the Caribbean.

DEVELOPMENT OF HILLSIDE FARMING IN THE CARIBBEAN

Domestic production of food crops continues to play a significant role in the development of Caribbean economies despite the persistency of a plantation system that had its beginnings in the early seventeenth century, perhaps earlier. In fact, Caribbean agriculture today displays a dualism that many feel is largely reponsible for the region's slow progress towards economic development. Large-scale, capital-intensive plantations continue to exist side by side with labor-intensive, small-scale hillside agriculture. The distribution of fertile, less steep land is biased towards the former.[2] The system as it exists and operates within the Caribbean is not very different from models present in many developing areas, perhaps differing only in the pattern of ownership and redistribution.

One can hardly examine the domestic agricultural sector without reference to the plantation system and what it stands for. Plantations do not always practice monocropping. As early as 1652, plantations were found to be producers of yams, corn, cassava, plantains and pasture in a system that was fully integrated with sugarcane (major crop). Even today, in Barbados, plantations are still producing some of these crops, while in Jamaica efforts are being made to introduce vegetable production into the system; plantations in St. Kitts-Nevis are being encouraged to grow peanuts and cassava. The operations of plantations are becoming more diversified.

The plantation system has been described in various ways. Innes (1972) refers to plantations as a system of settling empty lands through the importation of labor, capital and technology. The literature also suggests that plantations developed because the "demands of land, labor and capital discouraged the growth of free peasantry." Beckford (1972) described the plantation system as the totality of institutional arrangements surrounding the production and marketing of the plantation staple. It is a type of settlement that brings labor and capital from elsewhere.

We are not concerned in this paper with the details of various definitions and theories concerning plantations, whether they are more efficient than small-scale agriculture or whether they represent a more efficient allocation of resources. What we are concerned with is the way in which they impinge on or interact with hillside farming. Many plantations occupy flat lands and hilly lands.

As an institution, the plantation system, some say, represents a bastion of "resource immobility"; has a pattern of resource use that is generally out of phase with society's needs and instead is geared to the needs of metropolitan countries. Plantations monopolize excess land for speculative purposes as well as to secure labor, which leads to underutilization of land. When coupled with the reluctance of Caribbean people to work on plantations and the limited land available for their own production,

[1] Jamaica, Trinidad & Tobago, Barbados, Antigua, St. Vincent, St. Kitts-Nevis, Montserrat, Dominica, Grenada, St. Lucia, Belize, and Guyana.

[2] For a complete description of farm size and agrarian structure that characterize Caribbean agriculture—see Wilson (1976), "General Problems of Soil Erosion and Disturbed Lands in the West Indies with Particular Reference to the Commonwealth Caribbean," paper herein.

plantations contribute to gross underutilization of labor. As Beckford (1972) further suggests, this results in gross under-consumption by the majority of the population, together with gross under-utilization of resources.

All available evidence suggests that hillside farming in the Caribbean had its early beginnings prior to slavery, gathered momentum during and after emancipation, and matured subsequently. This pattern varied from country to country. Whenever labor was not required on the plantations for producing sugar, slaves were allowed to grow their own subsistence crops on the mountainous backlands of the plantations (Beckford, 1972). Indeed, many of the Caribbean countries are mountainous. Production of food crops on the mountainous backlands continued with renewed vigor after emancipation, especially on islands where the supply of land was not a serious constraint. Ex-slaves expanded their production of food crops in an effort to "maintain their freedom and independence." This led to a serious shortage of labor on plantations, which in turn had to import labor from elsewhere. But this was not always the case, because on islands where the supply of land was limited, ex-slaves had to sell back their labor to some of the plantations from which they had been freed.

Imported labor, together with the introduction of capital, machinery and favorable prices, enabled plantations to expand on a larger scale than before, with the result that they held for speculation more land than was required for production. This action further reduced availability of lands to the emerging new breed of small farmers.

Agricultural policies that were developed later in the post-emancipation period paid no attention to hillside farmers because, in fact, there were close links between policymakers and the landed-class. In fact, they were not separate individuals. The fact that hillside production is significant in economic development today is a tribute to those individuals that persisted despite these enormous barriers.

Still today, the plantation system dominates the agricultural, social and economic life of many of the Caribbean countries, at least those whose resources endowments are still largely agricultural. Most of the crops grown are oriented towards the export market—sugarcane, banana, coffee, cocoa, and citrus. One study of this dependency on the export market showed that banana, a major export crop, represented over 80% of agriculture's contribution to gross national product for one year.[3] Where agricultural production is restricted because of steep slopes, the best pockets of land are used to produce export crops. This reflects an agricultural policy preoccupied with exporting.

Production of food crops for the domestic market was always deemphasized. It took events such as the recent world wars to force a policy of food crop production, and this was because it was no longer safe to import foodstuffs from Europe. Food crop ordinances were established making it mandatory for estates/plantations to devote a certain percentage of their lands to the production of such crops as yams and sweet potatoes. Originally, the intention was not so much to produce food for local consumption, but to make sure that there were enough of these items available to supply friendly ships during the War. These regulations are still in existence in at least two countries, Barbados and St. Kitts-Nevis. However, in the case of the latter, most of these estates are under state control. There these rules may not now be operative since the idea is to utilize these lands in a manner consistent with national and regional, rather than private, interests. In any case sugar still predominates.

Another stage of the history of hillside farming worth noting is the use of statutory bodies to administer and operate commodity-based research and development programs. The Banana Board in Jamaica protects the interest of banana growers, the Citrus Growers Association citrus growers, and the Coffee Board coffee growers. There is yet to be created one such body for yams and sweet potatoes. A Sweet Potato Growers Association exists in St. Vincent, one of the major producers of the crops in the region, but no research on this crop is carried out by this organization. Irish potato growers in Jamaica have organized into a powerful cooperative but the emphasis is on marketing. Jamaica has achieved self-sufficiency in Irish potatoes after about ten years, largely because of the activities of this cooperative. Small quantities of potatoes are also exported to CARIFTA-CARICOM countries.[4] However, each year seed material has to be imported from either Europe or North America. Irish potato is produced in the hilly areas which are cooler and more suited to the crop. Attempts have been made to produce the crop on lowlands with varying degrees of success. Other farm organizations have been unable to service all these crops.

The majority of the research and development efforts on domestic food crops are carried out either by the various Ministries of Agriculture, which can only afford modest inputs, or private corporations which are either interested in fertilizer sales and insecticide or herbicide screening. Recently the Jamaican yam industry was conservatively valued at

[3]Yankey, J. B. 1974. "The Experience of Agriculture and Rural Sector in Economic Development (with special reference to Dominica)." *Proceedings of the 9th West Indies Agr. Econ. Conf.*, U.W.I., St. Augustine, Trinidad.

[4]CARIFTA-CARICOM refers to the Caribbean Free Trade Area now called the Caribbean Community.

more than J$30 million; research inputs totaled less than one-tenth of this amount. A yam research effort at the University of the West Indies has led to the development of yam flakes. But even though the product has been test-marketed, a major industrial breakthrough has not yet been achieved. These examples show that yams and other small farmers' crops are not receiving the attention due to them, even though they are expected to make significant contributions to the future development of the region.

What this discussion indicates is that from an historical perspective, food crop production in the Caribbean has had a rugged passage and only in times of emergency have these crops received any attention.

MAJOR CROPS GROWN, LEVELS OF PRODUCTIVITY AND ECONOMIC PERFORMANCE

Two crops dominate hillside farming in the Caribbean, yams and sweet potatoes. In some areas they have outperformed sugarcane, the major plantation crop, on a per hectare basis. Several research reports indicate that yams can generate higher net returns than sugarcane. However, it is difficult to find a crop that can replace sugarcane on a purely economic basis. Further, it is perhaps unfair to compare sugarcane with yams since their uses differ. The former has to be processed while the latter can be used for direct human consumption. Also, yam-based products have not been exploited in the same degree as sugarcane. This should not be interpreted to mean that small farmers do not grow sugarcane, bananas, or any other of the export crops. It is estimated that small farmers contribute well in excess of 30% of total production of these crops.

The experience with yams and sweet potatoes varies considerably from area to area. For example, in countries where sugarcane and bananas are produced on a large scale, other food crops are of secondary importance, while in others, where the terrain permits, there is a good mixture of bananas, yams, vegetables and other hillside crops. The typical pattern is that yams and sweet potatoes are located on the steeper slopes while the other vegetable crops are cultivated on the lower levels. There is justification for this pattern; yams requiring clean cultivation techniques are planted on steeper slopes because "erodable soils" are uncommon in these areas; the eroded soil being deposited on the lower levels could be potentially more productive, hence the location of higher-priced vegetables. But, in general, market considerations, land and labor productivity and topography tend to influence both crop location and production sequence.

Table 1 presents data on slope distribution of the total area of Jamaica. This data probably represent physiographical conditions of most of the other islands. Only Barbados, Guyana, Belize and Trinidad have lands with more moderate slopes and in those situations sugarcane is the dominant crop. In Jamaica more than one-half of the land is situated on slopes of 20 degrees or more, while only about 16% is on slopes of 5 degrees and less. Wilson (1976) estimated that ground provisions, selected vegetables and legumes (mainly small farmers' crops) occupied approximately 51 200 ha of land, the majority of which (80–100%) were located on sloping land. Sugarcane occupied some 167 000 ha of which 35% was located on slopes.

TABLE 1. Slope distribution of total area of Jamaica

Slope Classes	Degree	Percentage of Total Area	Estimated* Area (ha)
A	0–2	7.7	68 530
B	2–5	8.3	73 870
C	5–10	12.8	113 920
D	10–20	16.5	146 850
E	20–30	26.0	235 850
F	>30	25.0	222 500
Unanalysed	—	2.9	25 810

*Computed.

Source: UNDP/FAO. 1973. *Forestry Development and Watershed Management in Upland Regions of Jamaica.*

In many countries, active crop production ceases at 30 degree slopes, after which forest crops dominate. In the Caribbean, most hillside farming occurs at this range and above largely because of unavailability of lands at lower ranges. In many cases too, these lands are considered marginal and rent is minimal. Sometimes there is no charge for their use since the land belongs to the "Crown" and is often used unchecked. As can be expected, producing crops at such elevations is laborious and expensive and tends to discourage large-scale investments.

The majority of investments in hillside farming have been of a temporary nature. Such practices as rudimentary terracing and planting on contour ridges were introduced years ago, but with little success. Terraces were never wide enough to permit widespread use of small hand tractors or modest use of horsedrawn equipment.

As a rule, small farmers lack necessary capital to invest in infrastructural development on hillsides on a sufficient scale to stimulate and increase efficiency of production. The costs of such activities are often prohibitive. Moreover, there is a great deal of reluctance to do this because of unsatisfactory tenure arrangements. A large portion of the areas farmed are lands "captured" from either public or private sources. In such cases it is only a matter of time before these tenants are evicted from those

lands. Since the majority of the lands owned by the small farmers are less than two hectares, conservation practices such as terracing might lead to reduction in net acreage available for production.

Where tenure arrangements are agreed upon, these tend to operate in favor of the landlord whose primary interest is to collect rent. Since the areas rented are frequently marginal in terms of production, efficiency and perhaps accessibility, there is no need to invest in such lands except in crop systems which emphasize forestry. Forest production is a long-term investment from which future benefits accrue to landowners or their heirs. In the meantime, small farmers are allowed to cultivate areas between the trees during early stages of growth and under the trees as the forest approaches maturity.

Table 2 presents data on distribution of farms according to land tenure arrangements in St. Vincent. The data show that approximately 67% of farms between 0.5 and 10 ha are owned while the remaining 33% had some form of tenure. Significant variations are found among the groups; e.g., approximately 15% of farmers with less than 1 ha pay nominal rents or farm free of charge, while only 3% of those in size group 4–10 ha enjoy similar tenure privileges. As farm size increases, the tendency towards full ownership also increases.

TABLE 2. Percentage distribution of farm holdings according to types of tenure, St. Vincent

Category of Tenure	Percentage Frequency by Size Group (ha) 0–.5	.5–2	2–4	4–10	10+	Total
Owned	72.1	63.1	67.5	79.5	100	67.6
Rented	10.4	10.6	5.8	0	—	9.6
Nominal rent/rent free	15.4	13.7	4.8	3.0	—	13.2
Share tenancy	1.3	5.0	5.3	9.0	—	3.5
Land tenure	0.7	0.9	0	3.0	—	0.8
Mixed tenure	0.7	7.6	16.5	5.4	—	5.3
All farms	100	100	100	100	100	100

Source: Basic data obtained from a "Study of Small Farms on the Small Farm Sector in the Caribbean," currently in progress.

Failure of private interests to invest heavily in hillside farming means that any such investment must be performed by the state. And since many of the Caribbean countries have experienced capital scarcity they perhaps chose the most inexpensive method of investing in hillsides by expanding reafforestation programs first in areas exploited by shifting cultivators and later into other areas. This pattern offers direct competition to small farm production because it reduces the lands available for hillside farming. However, such programs are beneficial because they provide both skilled and unskilled employment for the people.

Table 3 presents data on some of the major crops grown by small farmers on hillsides in Jamaica for the period 1967–71. Also shown is a trend in their productivity over the years.

TABLE 3. Performance of selected small farmers' crops, Jamaica, 1967–71

Crop	Yield per ha (Tons) 1967	1968	1969	1970	1971
Potatoes					
Irish	13.11	8.34	11.12	11.36	10.82
Sweet	8.07	6.92	8.89	8.15	8.79
Cassava					
Bitter	13.41	10.02	9.88	10.13	10.22
Sweet	9.19	7.53	5.43	7.90	7.88
Yams					
Lucea	12.27	11.75	16.96	13.58	12.89
Negro	14.05	11.73	12.84	16.05	14.77
White	11.43	11.63	11.86	10.87	12.42
Yellow	10.82	12.57	12.35	11.28	12.39
Legumes					
Beans, broad	1.01	0.81	0.79	0.88	0.79
Pea, cow	1.25	0.88	0.93	1.19	0.96
Pea, pigeon	0.76	0.66	0.69	0.79	0.64
Peanut	1.21	1.01	0.76	1.16	1.08
Other Vegetables					
Carrots	7.01	5.93	5.68	6.67	7.28
Cucumber	10.59	11.48	11.11	7.90	8.45
Tomatoes	12.32	9.90	10.12	9.63	9.83
Fruits					
Pineapples	11.61	8.83	12.10	11.26	11.71
Watermelon	6.79	9.29	10.62	15.07	11.51
Cereals					
Corn, ordinary	1.28	0.93	1.23	1.48	1.41
Corn, sweet	4.94	2.89	4.44	3.95	4.39

Source: Agricultural Planning Unit (1971). *Report on Domestic Food Crops—Pigs and Poultry.* Ministry of Agriculture, Jamaica.

One feature that is characteristic of all these crops is their low levels of productivity. In no case did yield per hectare achieve acceptable levels or even come close to similar yields obtained under experimental conditions. Further, with the exception of yams, one can seldom detect any real improvement in productivity levels over the period under observation. A majority of the yields show declining trends in productivity. This is a clear indication that the level and rate of technology adaptation in producing these crops are low. In fact, yield increases that occurred in yams were largely due to new fields that were brought into production.

This state of affairs exists despite the presence of guaranteed prices and various subsidy programs. It is also evident from these trends that research

results are not reaching farmers at desirable rates. In fact, the majority of the production systems in use have not been changed over the last twenty years.[5] One of the primary reasons why the production system remains unchanged is that research on these crops has not yet emphasized development of a complete package of practices that are applicable under field conditions. The packaged approach is a technique that has been tried with a great deal of success elsewhere. For example, scientists participating in the University of the West Indies research program on root crops were able to bring about a four fold increase in yam yields in St. Kitts-Nevis by introducing a complete package of systems—method of land preparation, adjustments in spacing, introduction of weed control and, perhaps one of the most important features, a change in the size of planting material. Traditionally, yam growers were getting just over a 2:1 return from their planting material. These ratios were increased to almost four times the previous levels. Total saleable yields increased from 3.12 tons to 11.9 tons per ha as a result of these changes. Profit levels were also improved because even though prices had increased between the two study periods 1970 and 1973, costs per unit remained at the same level and while net returns were increased six times, largely because of increased yields. Comparable results were also obtained in similar studies conducted in Barbados, another major yam producing area in the Caribbean.[6]

Consolidated cost and return data to yam and sweet potato production in various countries of the Caribbean are presented in Table 4. The information should be interpreted with caution since considerable time has elapsed since these data were generated. Also, price increases might reverse the positions but they are not expected to distort the picture significantly.

The situation in 1970 was that small farmers in Barbados were producing an average of about 19 tons of yams per ha compared with 10.9 tons in Jamaica, 8.2 tons in St. Kitts-Nevis and 6.2 tons in St. Vincent. These operations were most profitable in St. Vincent, St. Kitts-Nevis and Barbados, while losses were being incurred in Jamaica. Again, Barbados small farmers were the leading sweet potato producers with respect to yield and profitability, but both yield and profits were lower than those obtained for yams.

One of the major reasons for these differences in performance is that both yam and sweet potato producers in Jamaica and St. Vincent operate at higher elevations than their counterparts in St. Kitts-Nevis and Barbados. Farmers in the former countries are therefore less able to apply mechanized technology compared to those in the latter countries. Because of the terrain, labor requirements tend to be higher in Jamaica and St. Vincent than in Barbados and St. Kitts-Nevis. Labor requirements ranged from about 131 man-days per ha on a small farm in Barbados to 151 and 205 man-days in Jamaica and St. Vincent, respectively.[7] In general, labor together with planting material and stakes constitute the bulk of the costs of producing yams in the Caribbean.

TABLE 4. Cost and returns to yam and sweet potato production in selected countries of the Caribbean, 1970

Items	Barbados	St. Vincent	Jamaica	St. Kitts-Nevis
(a) *Yams*		*Dollars*		
Cost per ton	126	330	140	120
Gross returns per ton	140	230	105	200
Net return per ton	14	100	−35	80
Saleable yields (tons/ha)	18.99	6.17	10.89	8.15
(b) *Sweet Potatoes*				
Cost per ton	66	116	135	120
Gross returns per ton	132	110	75	160
Net return per ton	66	−6	−60	40
Saleable yields (tons/ha)	12.18	4.20	7.98	3.46

Source: Compiled from data presented in Rankine, L. B. 1972. *Comparative Economics of Root Crop Production in Selected Countries of the Commonwealth Caribbean*, Part I, "Cost and Returns for Specified Root Crops." Occasional Series No. 8, Dept. of Agr. Econ. and Farm Management, U.W.I., St. Augustine, Trinidad.

CONTRIBUTIONS TO GENERAL ECONOMIC DEVELOPMENT

The importance of food crops to the economies of Caribbean countries can be measured in terms of their contribution to:

(a) food supply and nutrition of its peoples;
(b) employment and income;
(c) foreign exchange earnings; and
(d) sectoral linkages.

Neither data nor the scope of this paper allow for any elaborate analysis of these factors. However, it is hoped that the discussions which follow provide some crude assessment of these contributions.

[5]See T. Ferguson, Paper 47, herein, for a complete description of production systems.

[6]Rankine, L. B. and Ferguson, T. 1974. *Agro-economic evaluation of yam production in the Commonwealth Caribbean.* (In press.)

[7]Traditionally, one man-day is defined as 8 working hours—however, this definition no longer holds. The effective workday ranges between 5 and 7 hours.

Data obtained on the performance of agriculture in Jamaica give an indication of the overall performance of the food crop sector between 1962 and 1971. The contribution of the entire agricultural sector to the country's gross domestic product (factor cost) increased from J$52 million to J$68.9 million, for an average annual growth rate of 3.2%. Export agriculture, consisting mainly of sugarcane, showed a slower growth rate of 0.3%. Contributions of domestic agriculture grew by about 5.4% per year. The most significant growth rate was achieved by root crops, about 10.1% per annum.

Similar expansion in food crop production occurred elsewhere in the Caribbean and these results were due to several factors. Chief among them are:

(1). Integration of an import substitution policy within the broad framework of development objectives adopted by most Caribbean governments during the middle and late 1960's. Expansion of food crop production was seen as a major instrument in reducing the food import bill as well as for the diversification and structural transformation of the various economies. Guaranteed prices were used as a basis for stimulating production. The inward look toward the domestic agricultural sector was also due to adverse trends in the terms of trade for traditional export crops such as coffee, sugar and bananas, as well as the failure of industrialization policies to bring about desired changes in the economy.

(2). A meaningful start to the process of economic integration among Caribbean countries. The creation of the Caribbean Free Trade Area (CARIFTA) was intended to widen the market for the local foodstuffs. Special provisions were made in the CARIFTA agreement to facilitate trade in these commodities. A marketing protocol was created and some twenty agricultural commodities were included under it. Among them were carrots, peanuts, sweet potatoes, Irish potatoes, pigeon peas and string beans. These were basically small farmers' crops since at that time very few plantations cared for these crops.

As expected, there were teething problems in the operations of the protocol both at the national and regional level. Transportation, information, price control and other institutional rigidities had to be adjusted to make the agreement work. Also, there was some discussion as to direction of the major benefits of the program since the countries were at different stages of economic development. Further adjustments had to be made to accommodate problems peculiar to some of the members of the Free Trade Area. The Area has recently developed from CARIFTA to CARICOM which represents a deepening of the integration movement.

Time does not permit us to evaluate the impact of the integration process of agricultural development in the region, but one important effect is the creation of economic opportunities among the countries that previously remained untapped or unexploited. But it soon became clear that national programs would have to develop at faster rates than previously. Indeed, agriculture began to receive the attention it was due. Increased capital investments in the agricultural sector were effected in many countries. Johnson and Strachan (1974) for example, noted that the amount of fixed capital formation in Jamaica's agriculture increased from J$10.3 million in 1962 to J$12.6 million at the end of 1971. Investments in agricultural machinery alone increased from J$2.3 to J$7.4 million. One can only speculate that some of these facilities were shared by the domestic agricultural sector.

(3). In 1968, the University of the West Indies Faculty of Agriculture began what was to become the most comprehensive program on root crop research in the Caribbean. Previously, research on these crops had been conducted on an ad hoc basis in many of these countries. The basic idea of the program was to elevate these crops from the low status given to them into a viable root crop agro-industry through the introduction of alternative uses for these crops. Nearly all the disciplines in the faculty were engaged in various aspects of the program. At about the same time, the activities of the Caribbean Food and Nutrition Institute were expanded to examine the nutritional and economic aspects of local food groups. Existing information on the nutrient composition of various foods was collated and made available to Caribbean peoples. Those food crops on which information was lacking were also analyzed and incorporated into the booklet. An educational program was also launched to increase awareness and influence people's attitude toward these foods. The success of these activities can be measured by the fact that at least two countries have developed food and nutrition policies based on the information contained in the published document together with other assistance provided by the Institute. Several other institutions are at work trying to educate local people on the importance of local food groups.

Food Supply and Nutrition

The Commonwealth Caribbean countries obtain their food supply from two sources, imported commodities and local production. In general, dependency on imported foods in some of the countries has increased significantly, while in others it has been reduced. In 1974 the total value of foods imported into the Caribbean was estimated at approximately $804 million. By and large, the import content of the Caribbean food supply still remains high. This pattern has persisted because of dependence on tourism, failure to mobilize resources for

TABLE 5. Per capita food consumption by countries, 1971

Food Items	Jamaica	Barbados	Trinidad & Tobago	Guyana	ECC*
			kg/yr		
Cereals and cereal products	86.0	94.1	118.6	112.3	52.7
Rice	18.6	27.3	37.2	59.1	6.8
Wheat flour	55.9	58.6	65.4	50.9	45.0
Corn and meal	9.1	7.7	0.9	0.9	0.5
Others	2.7	.45	15.0	1.8	0.5
Root and starchy vegetables	201.0	93.2	58.6	82.3	137.7
Sugar	45.0	57.2	31.4	41.8	27.2
Pulses and nuts	6.4	10.9	15.4	6.4	3.2
Vegetables	28.2	30.0	62.7	29.1	9.5
Fruits	79.5	34.1	63.2	26.4	137.3
Meat	32.3	57.2	37.7	15.0	28.2
Fish	19.1	22.3	14.5	20.0	15.0
Eggs	4.1	3.2	6.4	2.3	3.2
Milk fresh	19.5	25.9	11.4	25.9	6.4
Milk evaporated	18.2	16.6	27.7	15.9	6.4
Oils and fats	14.5	10.0	18.2	11.8	9.5

*ECC refers to Eastern Caribbean countries—St. Kitts-Nevis, St. Vincent, Grenada, St. Lucia, Antigua, Montserrat, and Dominica.

Source: Shillingford, J. D. and Blades, H. W. 1975. "Prospective Demand for Food in the Commonwealth Caribbean." *Proceedings of the 10th West Indies Agricultural Economics Conference*, Plenary Papers, Vol. 1, pp. 40-53. Dept. of Agr. Econ. and Farm Management, U.W.I., St. Augustine, Trinidad.

Note: Original data have been rounded off for typographical ease.

local food production and perhaps limitations with respect to production possibilities.

Table 5 summarizes the food habits of Caribbean peoples on the basis of data collected for 1971. Even though there are differences in the quantities consumed, the consumption patterns are similar among the countries listed. Major food groups are roots and starchy vegetables and foods comprising the cereal and cereal products group. Even though no breakdown is given for the former, it is common knowledge that yams, sweet potatoes, Irish potatoes and cassava dominate this group. Both groups of food constitute basic food staples of Caribbean peoples. This dependency on such foods as a source of supply is so great that vitamin deficiencies are detected among certain groups of people from time to time. This condition is often a manifestation of the low intake levels for the other food groups noted in the table.

The contribution of selected food groups to available protein and energy supplies by sources for Jamaica is illustrated in Table 6. For example, cereals provide about 31% of total daily consumption of energy but only 5% is obtained from local foods.

TABLE 6. Contribution of selected food groups to available protein and energy supplies per capita per day, Jamaica, 1972

Food Group	Energy Total	Energy DS*	Energy IS†	Protein DS	Protein IS	Protein Total
		Percent				
Cereals	31.4	5	95	4	96	31.1
Starchy roots and tubers	14.7	100	0	100	0	13.1
Sugar & syrups	16.6	87	13	92	8	0
Pulses, oils and seeds	2.9	89	11	80	20	5.0
Vegetables	1.0	81	19	82	18	1.5
Fruits	2.8	85	15	91	9	2.5
Meats	6.6	54	46	99	1	17.5
Eggs	0.5	99	1	99	1	1.9
Fish	3.2	14	86	18	82	12.9
Milk and milk products	7.2	68	32	50	50	13.5
Oils and fats	11.3	62	38	50	50	0.2
Miscellaneous	0.3	8	92	38	62	0.4
Alcoholic beverages	1.5	86	14	90	10	0.4
Totals	100	54	46	37	63	100

*DS = domestic sources.
†IS = imported sources.

Source: Leslie, K. A. and Rankine, L. B. 1975. "Food Supplies in the Commonwealth Caribbean." *Proceedings of the 10th West Indies Agricultural Economics Conference*, Plenary Papers, Vol. 1, pp. 23-37. Dept. of Agr. Econ. and Farm Management, U.W.I., St. Augustine, Trinidad

On the other hand, of the 31% protein supplied on a daily basis, 96% is obtained from imported foods and only 4% from local foods. All the energy and protein supplied by roots and tubers are obtained from local food sources. Similar distribution is presented for all other food groups. The information in the table can be used to measure the relative degree of dependency on foreign and local foodstuffs. No consideration will be given to the question of relationship between this daily food intake and established norms. Neither will it be possible to indicate the total amount of food supplied by the domestic food crop sector on a regional basis due to inadequate data.

Contributions to Employment, Income and Foreign Exchange Earnings

Reference has been made to the fact that most Caribbean countries depend heavily on agriculture for their existence. However, it is still difficult to get an accurate estimate of the number of people employed in the agricultural sector. Unlike employment in export agriculture, it is extremely difficult to obtain information on domestic agriculture. Several figures on agricultural employment are tossed about. These range from 30-60% of the labor force. However, it was possible to provide some crude estimates on possible direct levels of employment

provided by the food crop industry for one particular year. These estimates were obtained by multiplying total production by the average number of man-days required to produce one hectare of selected crops. The data are presented in Table 7 for Jamaica. As suggested in the table, yams, other tubers and potatoes provide by far the highest employment levels, over 3.0 million man-days of employment. These figures do not include indirect employment generated by these commodities. By any standard, these figures are impressive, especially for countries as small as those in the Caribbean.

TABLE 7. Estimated production of main domestic food crops and man-day requirements, Jamaica, 1971

Crop	Production (Tons)	Total Number of Man-Days
Yams	135 435	2 444 384
Other tubers	48 860	1 209 167
Potatoes	36 146	764 606
Vegetables	68 110	1 739 783
Legumes	7 044	891 069
Cereals	5 758	890 010
Plantains	25 825	543 434
Fruits	12 416	298 060
Condiments	3 353	265 244

Source: Adapted from Johnson, I. and Strachan, H. 1974. "Agricultural Development in Jamaica." *Proceedings of the 9th West Indies Agricultural Economics Conference*, pp. 3–21, Dept. of Agr. Econ. and Farm Management, U.W.I., St. Augustine, Trinidad.

The analysis can be extended further to suggest contributions in terms of income-generating capacity. All one needs to do is to multiply these employment figures by minimum wage levels to get the total wage bill that must be paid by these crops. Even more impressive are the figures that result when total production is valued either at the farm-gate, wholesale or retail levels. If the 1971 figures are multiplied by a mere $400 per ton (current retail prices) a dollar value of $54 million is obtained. But the real question is how much of this goes to the yam farmer? Complete calculations of total production times various market prices will give a crude approximation of the relative importance of the domestic food crop sector in terms of income-generation.

Another dimension must be added to this discussion. Large portions of these items are sold both within the region as well as to North American and certain European countries. In normal times export prices tend to exceed domestic prices. If one estimates that yams are able to fetch about $750 per ton on the foreign market, and further assumes that about 20% of these yams are exported, then the value of yams in both the domestic and foreign markets taken together is likely to exceed the estimates given previously for yams. The situation is very much the same for other Caribbean islands. St. Vincent, for example, exports 2 500 tons of sweet potatoes annually to Trinidad, at a value of $3–5 million.

Exploitation of the export trade is being encouraged since foreign demand for these commodities appears to be expanding, especially among indigenous Caribbean and African populations in the United States, Canada and England. However, opportunities for expansion of these markets are conditioned by several factors. Chief among these are quarantine regulations, competition among suppliers and most important, transportation.

As a rule root crops are bulky and consumers may discriminate against them if they are considered in terms of nutrient cost relations. Transport problems are critical to both intra-regional and extra-regional trade in these commodities. However, processing activities would reduce the bulkiness as well as extend the effective life of some of these crops. The technology for transforming some of these commodities is available. All that remains is to implement plans for processing. Cassava is one of the crops that has been earmarked for rapid industrialization. Several processing plants have already been constructed but the cassava still has to be produced on the scale required to keep these plants operating at full capacity. These processing plants have been designed to process several commodities. Modest breakthroughs have already been achieved. For example, cassava flour has already been blended into wheat flour to produce an acceptable product. Similarly, as already mentioned, yam flakes are already on the market with varying degrees of success.

CONSTRAINTS TO PRODUCTION

One of the theories advanced herein is that the complete dominance of plantation crops with respect to land, labor, capital and perhaps managerial skills has been largely responsible for the slow rate of development in the food crop sector as well as in the general economic development of many Caribbean states. By having complete monopoly of lands with higher potential productivity and while not competing directly with domestic food crops in the narrow sense, the plantation system of production acts as a constraint to expansion of domestic food crop production. Further, the degree of mechanization as well as use of other inputs which could prove beneficial in terms of scale economics are also restricted by the buffer of land available for hillside farming. Because plantations are in a position to

offer year-round employment at wages that small hillside farmers can ill afford to pay, they attract more labor than small farms. Frequently, small farmers are forced to abandon their crops and sell their labor to plantation agriculture. Domestic food crop producers have to pay higher wages if they want to compete with plantation crops in the labor market. Because of the nature of marketing arrangements, plantation agriculture tends to be a safer investment and so is able to attract both foreign and local capital on a scale that small-scale agriculture can seldom achieve.

Availability of land and labor and the competition of their use therefore appear to be the most critical concerns for the small-scale hillside producer. Up to a few years ago one could identify vast amounts of idle lands throughout many of the Caribbean States. But the picture is gradually changing due to a more revolutionary approach to agricultural land utilization policies now pursued in many of these countries. Formerly, attempts were made to settle farmers on marginal lands without providing the necessary infrastructure and training in farm methods. A new approach is being implemented in Jamaica with some success. Small farmers and others "of proven agricultural experience" and "who are in genuine need of land" are being provided with supplemental tenancies. The state leases land from owners and sublets it to farmers for periods of five years or more. The idea is to provide farmers with additional land to expand their production. They are also provided with basic inputs in addition to the technical services of the Agricultural Extension Department.

Similarly, some of the bauxite companies operating in Jamaica are restoring mined-out lands for agricultural purposes. Also, where available, lands are rented to farmers prior to mining. Tenant farmers operating on bauxite lands are also provided with certain facilities such as training, marketing facilities and technical services. The land program is geared towards increasing the supply of land since land has been identified as a major limiting factor in food crop production.

In addition to redistribution of land, efforts are being made to ease the capital constraint by increasing the supply of production credit through regular commercial banks and other financial institutions specially designed to service the food crop sector.

But provision of additional land and credit, together with efforts to increase labor supply, are not by themselves sufficient to stimulate development in the domestic food crop sector. Other conditions must be met. There is general agreement that hillside farming in the Caribbean needs to be tackled on a more scientific basis in order to develop an appropriate technology. Besides the immediate increases that are possible, the long-term benefits of such efforts could become immeasurable. Since capital has been identified as a major limiting factor, ways and means should be devised to utilize this capital to obtain the maximum expected returns from hillside production.

One approach would be to reserve these areas for forestry as is customary, but even the establishment, upkeep and harvesting of forests are expensive operations. Another alternative is to use hillsides in a manner consistent with established and proven soil conservation practices. Crops grown on hillsides should be allowed to contribute to the maintenance of these practices since it is envisaged and expected that the establishment costs will be borne by the state. This proposition applies to forestry as well as to food crops. A cropping pattern that reserves the steeper slopes for forestry and fruit trees and diversion of less steep slopes to food crops seems feasible but is only possible where such lands exist. And this is hardly possible in such countries as Dominica, St. Vincent and parts of St. Lucia.

What is implied here is the need for a more rational and scientific approach to land utilization in the Caribbean. Jamaica is perhaps leading the way in this respect. With technical assistance provided by the UNDP/FAO, that country, in 1975, started a rather comprehensive program to develop a methodology for the effective management of its watershed areas. The project also includes studies on yam production since the area chosen for the first phase of the program was one of the major yam-growing areas of the country. The basic idea of phase one of the study was to introduce some changes in the production system and compare the results with the traditional system of growing yams. Yam cultivation as practiced in the Caribbean exposes the soil to the full forces of wind and rain. Mulching is done on rare occasions and is mostly used to control weeds and retain moisture. Yam fields are usually kept weed free until the vines achieve full cover. Early protection is given to the soil if plants are allowed to run along the ground, as is the practice in Barbados and St. Kitts-Nevis. But if staked, as practiced in Jamaica and St. Vincent, soil protection on hillsides largely depends on the spacing practices adopted. The period between land preparation and planting and when the plant achieves full cover could be as long as five months. If there is heavy rainfall during this period, heavy soil loss is incurred on hillside cultivations.

Terracing was considered an innovation because it is a soil conservation measure and it facilitates a great deal of mechanization of some of the yam-growing techniques in the area. Indeed, digging yam hills, banks or holes on natural hillsides is laborious and time-consuming. Sheng and Michaelson (1973) indicated the following changes in the production system in the UNDP/FAO research project:

(1) making contour mounds by tractor instead of hills made by hand;

(2) use of fertilizer;

(3) using 18-ft. stakes instead of shorter ones;

(4) closer spacing made possible by contour mounds; and

(5) cultivation of yams year after year without fallowing.

The traditional system adopted by farmers was simulated and incorporated into the experiments. Of immediate interest to us is the response of yam to the various treatments. Table 8 shows some of the results of the study.

TABLE 8. Production of yellow yams from run-off plots, Jamaica (tons/ha/yr)

Treatment	Year I	Year II	Year III	Year IV	Average
Bench Terraces					
Total production	35.3	44.2	32.6	37.8	37.5
Salable yield	18.5	30.4	21.0	23.2	23.2
Hillside Ditch and Contour Mounds					
Total production	37.5	44.5	39.8	37.3	40.0
Salable yield	20.5	29.6	26.2	23.2	24.9
Hillside Ditch and Hills					
Total production	43.2	47.2	37.1	35.3	40.1
Salable yield	24.9	33.3	25.2	23.5	26.7
Traditional Method					
Total production	56.3	53.1	33.1	26.4	40.0
Salable yield	31.6	37.8	22.0	16.8	26.9

Source: Adapted from Sheng, T. C. and Michaelson, T. 1973. *Run-off and Soil Loss Studies in Yellow Yams: Forest Development and Watershed Management in the Upland Regions*, Jamaica, UNDP/FAO.

The researchers identified two important findings:

(1) that continuous cultivation on the same plots for five years did not result in any appreciable nematode damage. Further, terracing did not result in any drastic decline in production; and

(2) there was no apparent deterioration in quality due to use of fertilizer and the product proved to be acceptable.

The first point is important because farmers generally prefer shifting cultivation because of yield losses and nematode infestation. In addition to the observations of the researchers, it can be noted from the information presented in the table that the new methods introduced consistently performed better than the traditional method in terms of total production. While results of Year I and Year II showed higher total production and saleable yields, all yields were lower than previously at the end of Year III. The decline in yield for the traditional method was the sharpest (20.0 tons between Year II and Year III and 6.7 tons between Year III and Year IV). Further analysis of the data shows that whereas the harvesting efficiency ratios (saleable yield/total production) in the traditional method were relatively higher in the early years, at the end of the observation period all the ratios were similar for the other methods of cultivation.

The study also suggested that soil loss at a rate of 14.8 tons and 9.8 tons per ha per year could be tolerated on deep and shallow soils, respectively, and that both weather and soil formation processes in Jamaica were generally higher than they are in temperate climates.

The overall results obtained are not surprising since experiments with yams elsewhere have obtained yields of approximately eight times the average figures presented in Table 3, but the results show once again the tremendous possibilities that exist for scientific exploitation of hillside cultivation. However, in the final analysis, whether traditional methods are indeed inferior to new techniques depends on the incremental benefits compared with the incremental costs. Similarly, choice among the alternative methods of producing yams on hillsides also depends on the criteria referred to above.

Very little has been said about the marketing system as a constraint on food crop production. It is general knowledge that the system as it operates tends to hinder rather than stimulate production of these crops, despite the presence of a guaranteed price system. Food crops are being forced into a marketing system copied from developed economies and very little attention is paid to modernizing the indigenous systems that have developed over the years. As a result, the two systems become competitive to the extent that they frustrate farmers.

FUTURE OF HILLSIDE FARMING AND PRODUCTION OF DOMESTIC FOOD CROPS

Current indications are that pressures on the domestic agricultural sector will increase significantly over the next ten years because the sector will be called upon to play a more strategic role in the social and economic transformation of Caribbean economies. But it appears that official agricultural policy will continue to emphasize export agriculture. Currently, investments in export agriculture are being made at a faster rate than in the domestic agricultural sector. For example, there is a massive rehabilitation program for bananas in the less developed countries of the region and to a lesser extent in the more developed areas. Sugarcane production is being expanded and re-introduced in various countries. Cotton is rapidly regaining prominence as an export crop. And too, foreign exchange earnings are still a development objective for many of the countries.

But if the policy of import substitution and self-sufficiency in food supplies continues to be a part of the development strategy, then domestic food crop production must assume greater importance.

Data in Table 9 show projected increases in per capita consumption, increases in total demand and annual average increases in these demands for specified food groups. The demand for cereal, cereal products and starchy roots and vegetables are projected to increase by 32 and 17.1%, respectively, by 1980. It appears, then, that possibilities for substitution between these two food groups offer the

TABLE 9. Regional consumption and projected demand (1971–80) for selected food groups

Food Groups	Per Capita Consumption 1971	Per Capita Consumption 1980	Total Demand 1971	Total Demand 1980	Percentage Increase in Total Demand	Annual Average Increase (%)
	kg/yr		*Thousand kg/yr*			
Cereals	93.7	105.9	417 790	551 045	31.9	3.1
Rice	28.2	29.5	125 563	153 446	22.2	2.3
Flour	55.7	65.9	248 525	343 003	38.0	3.6
Corn and meal	4.7	4.9	21 001	25 271	20.3	2.1
Others	5.1	5.6	22 701	29 325	29.2	2.9
Roots and starchy vegetables	134.5	134.9	599 308	701 911	17.1	1.8
Sugars	39.5	41.9	176 166	218 021	23.8	2.4
Pulses and nuts	8.4	9.5	37 399	49 378	32.0	3.1
Vegetables (non starchy)	33.9	39.4	151 048	204 784	35.6	3.4
Fruits	71.2	89.8	317 167	466 788	47.2	4.4
Meat	31.2	44.9	139 272	233 878	67.9	5.9
Fish	17.8	21.6	79 331	112 619	42.0	4.0
Eggs	4.1	6.5	18 160	34 358	89.2	7.3
Milk — fresh	17.3	22.6	76 969	117 947	53.2	4.9
Milk — evaporated	18.5	19.4	82 540	103 494	25.4	2.4
Oils and Fats — butter	4.8	7.4	21 755	38 365	76.4	6.5
Oils and Fats — other	9.2	10.6	40 885	55 475	35.7	3.5

Source: Adapted from Shillingford, J. D. and Blades, H. "Prospective Demand for Food in the Commonwealth Caribbean." *Proceedings of the 10th West Indies Agricultural* Economics Conference, Plenary Papers, Vol. 1, pp. 40–53. Dept. of Agr. Econ. and Farm Management, U.W.I., St. Augustine, Trinidad.

TABLE 10. Percentage distribution of increases in demand for specified food groups by 1980

Food Groups	Countries: Jamaica	Barbados	Trinidad & Tobago	Guyana	ECCM	Total
Cereals and cereal preparations	40.3	5.7	27.3	17.7	9.0	100
Roots, tubers and starchy vegetables	50.0	3.2	17.0	11.8	17.0	100
Sugar	45.3	4.8	24.0	15.9	9.8	100
Pulses and nuts	41.7	6.8	37.8	8.4	5.2	100
Vegetables	40.0	4.3	38.6	13.4	3.5	100
Fruits	46.3	2.1	24.8	5.4	21.3	100
Meat	45.4	6.2	32.9	6.1	9.3	100
Fish	45.2	5.5	25.9	16.6	6.8	100
Eggs	37.6	3.5	46.2	6.3	6.3	100
Milk — fresh	52.1	7.4	18.6	17.7	4.1	100
Milk — evaporated	38.7	3.6	40.7	12.3	4.6	100
Oils and fats	38.3	3.9	45.2	6.4	6.0	100

Source: Adapted from Shillingford, J. D. and Blades, H. W. "Prospective Demand for Food in the Commonwealth Caribbean." *Proceedings of the 10th West Indies Agricultural Economics Conference*, Plenary Papers, Vol. 1, pp. 40–53, Dept. of Agr. Econ. and Farm Management, U.W.I., St. Augustine, Trinidad.

greatest challenge to the domestic agricultural sector, since a majority of the cereals are imported. But in view of the comments on constraints to production referred to above, replacement or displacement of certain cereal products by roots and starchy vegetables will be a formidable task. Further examination of the data in the table shows that greater increases in demand are projected for foods with higher protein content than roots and starchy vegetables, e.g., demand for eggs will increase at a rate of 7.3% per annum compared with 1.8% per annum for roots and starchy vegetables. Consequently, the performance of the domestic agricultural sector will be affected by these and other changes noted in the composition of the demand for various foods.

Data in Table 10 can be used as a planning tool for the Caribbean since they described the projected percentage increases in food demand on a country basis. This information can be used to estimate additional acreage required to satisfy additional demand, given present consumption and productivity levels for the various crops. The implications for national agricultural program are therefore very clear. Drastic changes will have to be made in the approach to food crop production if the food supplies are to come from local sources. Some adjustments are currently in the making. Joint venture projects have been established between several Caribbean countries. The Caribbean Food Corporation will begin operations soon. The Corporation will promote large-scale production of various commodities having a high import content, e.g., corn and soya bean. Similarly, the negative list is being used to guide consumption patterns of Caribbean peoples.

Hillside farming will continue to be important with respect to basic staples, because they are still among the cheapest sources of carbohydrates. However, their long-run survival depends on the nature of increase in land and labor productivity. Agricultural labor is no longer readily available due to development of other sectors such as manufacturing and services and perhaps a growing reluctance of Caribbean people to continue in agriculture as currently practiced. The introduction of minimum wage legislations in agriculture will no doubt force farmers to improve their performance if they are to remain in agriculture. One logical reaction will be a switch to high-priced crops for which large increases in demand are projected. Thus the competing demand might introduce changes in land use patterns on hillsides. Fruits and vegetables are the crops most likely to dominate the picture in the near future.

An area worth considering is development of linkages with the plantation/export agriculture. Besides providing capital for investments in operations such as terracing and other infrastructural developments on hillsides, export agriculture might be encouraged to share production technology with domestic agriculture. The production technology referred to should be extended to include marketing as well. The prospects for futher advances in agro-industry can be improved if there is closer collaboration between the plantation and hillside farming in terms of land use and production. Together they can provide stronger linkages with other sectors of the economy. Research efforts on hillside farming technology need to be increased. However, the success of these activities will depend on the general political climate and its effect on economic development, particularly the role given to the agricultural sector. Caribbean leaders have yet to demonstrate a willingness to develop a permanent and viable agricultural economy.

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DISCUSSION

R. W. Brougham (New Zealand). You mentioned at the beginning of your talk that some of your land is either 100% or 51% owned by the state. Other areas of your land are owned by private individuals. Could you describe the differences in approach to management, for instance farm sizes, how you go about managing these and whether the state-owned farms are more productive than the privately owned farms?

Rankline. We have had a very interesting experience in Jamaica. When the state embarked on large-scale

mechanized production, mainly of imported commodities such as peas, some legumes and Irish potatoes, in some cases, at least during the early stages, there were significant increases in production. But later a political variable entered the picture and it became necessary to employ a significantly large amount of people (labor) in order to ease the unemployment problem. At that time costs of these enterprises were exceeding the returns. These are new ventures. I mentioned that the state had acquired some sugar plantations. They are now developing what we call sugarcane cooperatives. The management structure is largely retained but the workers are being slowly introduced to the managerial aspects of large-scale plantation management. The first step was to redistribute ownership. Workers would perhaps be a little more interested if they felt that they were participating fully in the activities of the plantation sector. I don't know if this will clear up your concern. We haven't been involved in this exercise long enough to evaluate the full effectiveness of these operations.

44.
Hill Land Farming: An International Dimension

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> . . . even the battles to purify the noxious clouds over Tokyo and Sao Paulo, and to restore life to Lake Erie are but skirmishes compared to the uncontested routs being suffered in the hills of Nepal and Java, and on the rangelands of Chad and northwest India. A far deadlier toll, and perhaps an even greater threat to future human welfare than that of the pollution of our air and water is that exacted by the undermining of the productivity of the land itself . . . Not surprisingly, the principal victims of these trends are the world's poor who, in their quest for food and fuel, are often forced by circumstances and institutions beyond their control to serve as the agents of their own undoing. Though poverty is often associated with a pristine environment, and affluence with despoliation, in some important ways the poor are damaging the environment even more than the rich. . . Today the human species has the knowledge of past mistakes, and the analytical skills, to halt destructive trends and to provide an adequate diet for all using lands well-suited for agriculture. The mounting destruction of the earth's life-supporting capacity is not the product of a preordained, inescapable human predicament, nor does a reversal of the downward slide depend upon magical scientific breakthroughs. Political and economic factors, not scientific research, will determine whether or not the wisdom accumulating in our libraries will be put into practice.
>
> —Erik P. Eckholm
> *Losing Ground*
> 1976

Contemporary economists are interested in hill farming because of the inescapable fact that all over the Third World, and at an ever-increasing pace, slopes and hillsides are yielding to the pressure of population growth. The phenomenon is hardly new; in every thickly populated region most fertile valley soils have long since been developed and exploited. In some established farming areas near the equator, public efforts to control such diseases as malaria and sleeping sickness, together with road construction, have permitted population to move from the highlands to the hot, humid lowlands. Governmental programs of irrigation and reclamation have allowed new or more intensive use of some other lowland areas. But most of the new land coming into agriculture through the efforts of individual farmers has been steep or sloping land, and population growth has relentlessly speeded its exploitation.

If economic implications were examined by themselves, some complex interconnections among social, biological, and physical factors would be overlooked. A simple description of what typically happens as hill lands are converted to farming may help to keep them in focus. Where hills are a predominant topographical feature, the trees in the valleys are first removed to make way for sedentary agriculture (often row crops). Forests in the highlands continue to protect life in the lowlands, providing ground cover for easily erodible slopes and also furnishing firewood for the valley dwellers.

As population grows, young people establish new farms or enlarge their holdings by pushing on to foothills and even steeper gradients, necessarily cutting the trees that grow there. When trees at these levels have been removed for farming, rural families begin to take firewood from even higher slopes. As

the forest border recedes, more and more hillside soils (which are often of lower quality) and forest litter wash down into the valleys overcovering prime fields. As forests become increasingly distant, cow dung becomes a reasonable substitute for firewood as fuel. (Kerosene is usually much too costly for day-to-day use in farming communities of the kind we have been describing.) Every unit of dung burned as fuel means one less unit available to restore the natural fertility of the soil.

In the humid tropics, the picture involves additional complexities. Because rainfall there is so intense, the destruction of ground cover for row crops is a questionable practice even in the valleys. When hillsides are laid bare, rivers and irrigation canals become clogged and valleys silted with startling swiftness.

The consequences I have described are dramatic, but their coming is so gradual (and, once begun, so inexorable) that little has been done to modify their impact on the livelihood of people in the immediate area or other areas linked to it by ecology, products sold, or labor exported.

This simple case is repeated, with infinite variations, in dozens of poor countries today. For many of them it has been translated into the dominant issue of the food-population-environment controversy.

Growing consciousness of the breadth and seriousness of this problem is sure to bring insistent demands for economists to contribute to policy analyses. To do so, they will need many of the traditional economist's tools and kinds of data: costs, returns, and feasibilities for this steady movement up the slopes compared to the alternatives of using existing land more intensively, moving people elsewhere, or generating non-agricultural employment, costs and availability of firewood, kerosene, electricity and other fuels. But an economist's policy prescriptions will be grossly misleading if he does not also utilize data on soil and weather in evaluating the capability to sustain human enterprises at successively higher locations and the feasibility of such soil conservation procedures as contouring and terracing. How do different kinds of soils react when ground cover is broken and they are exposed to intense heat and driving rainfall? (If heat is intense enough, nutrient sources may be destroyed; if water movement is rapid enough, nutrients themselves may be washed away.) How do new crops or new varieties respond to soils and water or fertilizer treatments to which they have not before been exposed? What constraints of imagination and action do the people face when they have no off-farm employment opportunities, uncertain or insecure rights to the land they farm, no experience (or bad experience) with group action to solve their problems, and little community leadership or group identity? What problems are posed when this process results in a face-off between two cultures, one from the mainstream and the other for centuries closed off from it? Issues like these remind us of the futility of studying problems of humans as if they were packaged as disciplinary units. Although I will try to extract some of the socio-economic problems from questions like this, it should be obvious that they cannot be treated adequately without the expertise of the agronomist, the soil scientist, the engineer, and the botanist.

Economists who study hill lands in the context of the contemporary international food problem tend to focus on marginality of agricultural production, an issue best formulated in an earlier epoch by Ricardo, one of the first true economists. In 1817 he provided a theoretical framework linking capital, labor and land which posited the centrality of the population-agriculture issue. He saw land as the factor which ultimately would limit economic expansion. In meeting larger demands for food, he reasoned, successive employment of units of either labor or capital on a land supply that is essentially fixed will bring diminishing returns of agricultural output to those factors.

As poorer lands are brought under cultivation (the idea that the supply of land is fixed was modified only by the fact that less agriculturally apt land could be added), competition among those who farm for the better grades of land causes a portion of the produce of the land to be transferred to landowners. This return is "rent," or that portion of the produce which is paid to the landlord for the use of the "original and indestructable powers of the soil."

Ricardo's views were in marked contrast to the philosophical optimism of many thinkers of his time; his theoretical constructs at the same time brought some rigor to Malthus' pessimism. William Godwin in 1793 had excoriated the present but had seen a future in which "there would no longer be a handful of rich and a multitude of poor. . . (T)here will be no disease, anguish, melancholy, or resentment." It was inevitable that such optimism would bring a reaction, and Malthus, in providing it, formulated the raw material for Ricardo's ideas. Malthus wrote in 1798 that population would outstrip all possible means of subsistence. Far from ascending to higher levels, mankind was caught in a hopeless trap in which it would be driven to the brink of existence, condemned to a losing battle between population growth and the insufficiency of nature's larder.

Ricardo was responsible for casting Malthus' ideas into a theory—now we would call it a model. His early eighteenth-century economic world was dynamic, but the stationary state was right around the corner. As capitalists reinvested, new shops and factories would appear. Demand for laborers would

increase, but their temporarily higher wages, he prognosticated, would simply mean that workers would multiply faster. As they did, more food would be needed, and poorer and poorer lands would be required to feed the now expanded labor force. In Ricardo's formulation, the capitalist makes growth possible because he reinvests. Since food supply couldn't expand fast enough, the selling price of agricultural produce would rise and, naturally, so would the returns (rent) to landlords. But the landlord's rent is not reinvested and, in order for Ricardo's construct to make sense, the landlord and the capitalist are never the same person. The process of growth squeezes the capitalist doubly: first, by an increased number of workers, to whom he must pay at least a subsistence wage; and second, by the landlord—a most pernicious character—whose rents rise as less productive land is pushed into cultivation. If capitalist and worker are the active participants in the economic process, the landlord is at best a passive beneficiary. When wages rise to reduce all profits to zero, the growth process stops, for the capitalist has no more incentive to invest.

For most of humanity, the nineteenth century did not see the dreary outcome presaged by Ricardo, nor has the first three quarters of the twentieth. Some believe his ideas to be hopelessly dated; I believe that to avoid their implications will take positive planning. When wheat fields began creeping up the hillsides of England in the last century, they were stopped by a rather simple mechanism: imports of grain. Industrialists lobbied hard for freer international trade and cheap food for workers, and they got it. Also, Malthus and Ricardo were wrong about population growth for their era: it did not proceed on the rampant course they had forecast. Another limitation, perhaps the most decisive, in Ricardian theory was its lack of recognition that there are more ways to increase agricultural production than by simply bringing more land into production. The unprecedented innovations of the last century and a half made it possible to keep food production up with population growth without moving to successively poorer land. Indeed, applying technology to produce a surplus in areas naturally suited to agriculture has been the cheapest way to add to the indigenous food supply.

There is another side to this coin. Just as Ricardo didn't foresee land-saving technology, neither did he, writing in England where rainfall is gentle and hills are slightly rolling (and at the time quite amply covered with natural grass and trees), imagine the havoc that man could wreak by despoiling natural resources.

But the food-population issue is again before us, about a century and a half after Ricardo set down his thoughts in orderly form. Now, the setting is different: the contemporary less developed countries—which were then underpopulated and entered into no one's calculus—are the problem. Today, the ideas of these dour first social scientists look less preposterous than they did even a decade ago:

1. Population is growing at a rate unprecedented in human history and it is more than simple tautology to observe that this growth is greatest where agricultural land is under the most pressure. Most demographers think that the current population of the world will not quite double by the end of the century, but exactly how fast it is growing is a moot point—growth is quick enough to cause alarm to every thinking human being. Even now the experts are having a difficult time figuring out how more can be produced in some areas, or, where there are bumper crops, how they can be distributed from those who have too much to those who don't have enough.[1]

2. The margins for sustaining less developed countries through international trade are not so large as in the recent past.[2] The United States is the largest exporter of grain, but most must be paid for in hard currency. The prospect is that, if events continue on their present course, less developed countries will become increasingly dependent on the United States, an unsatisfactory solution for both us and them.

3. Most dramatic increases in rates of population growth are occurring in tropical areas where we know least about producing more from a fixed land base; most of our agricultural technology comes from the temperate zone. It is one irony of soils in the tropics that somewhat sloping lands may be more attractive for farming purposes than flat land because the hills receive nutrients from the underlay of parent rock. Some combination of heat, moving water, and rock results in soil formation. Flatlands may have little mineral base or minerals are leached out. Of course, if hills are too steep, soils may be formed

[1] With a number of provisos, the tone of one recent compendium of articles on the world food problem is more optimistic than most. See *Scientific American*, "Food and Agriculture," September 1976.

[2] Of course, there are resources that, at a substantial cost, can be pressed into use in developed countries to produce what less developed countries need. "The best arable land in the United States is already in production. . . . To feed a growing U.S. population or increase the world per capita diet (or both), the amount of cropland under cultivation can be increased or the productivity of the land already cultivated can be increased. Either course would require enormous amounts of energy and could not be continued indefinitely. Major reclamation projects would be required to drain, grade, and irrigate the estimated 75 million acres [30.36 million hectares] in the United States that are potentially arable." D. Pimentel, *et al.*, "Land Degradation: Effects on Food and Energy Resources," *Science*, 194 (October 8, 1976), 153. Currently about 154 million hectares of the arable land in the U.S. is under cultivation.

and quickly made inaccessible because of erosion. So life becomes an important balance between such factors as degree of slope, speed of water, depth of mineral source and temperature. Research is required to find that balance.

4. Despoliation of the environment due to overgrazing, erosion, and leaching is rampant. While it has been so for years, it is more serious now and has been recognized as a critical worldwide problem only in the last decade or so. (Of course, it was considered serious in the United States, beginning with the dust-bowl days of the 1930s, but an international problem wasn't recognized.)

So in addition to curbing population growth and increasing production, some attention needs to be given to the preservation of marginal areas such as hillsides, which are increasingly being inhabited and expected to provide the sustenance for growing populations.

Of course, there are reasons other than the sheer pressure of population why people live on hillsides, and have done so for centuries, which have little or nothing to do with these exigencies of the modern day.

1. In some areas of the world, hills serve either as enclaves of cultural identity, as refuges from the discrimination of the lowlanders, or as convenient strongholds for those who are considered by the majority as the least desirable members of society (who would presumably otherwise have to be dealt with in more meaningful, probably integrative, ways). This depends on the country in question and the analyst's political philosophy.[1]

2. In some tropical areas of the world, less productive hills were occupied to escape the malarial lowlands. With the disappearing threat of malaria, there is movement in some countries to the as yet uncharted lowland areas. But the temperate climate, the familiarity of the environment, and the religious overtones which attend some ancestral lands hinder depopulation.

3. Some tropical hillsides are farmed to provide a more diversified cropping pattern, more work throughout the year, or for a more adequate, well-balanced supply of life's necessities than would be possible in their absence. In the tropics, small-acreage farmers may have sugarcane in the lowlands, temperate vegetables and row crops at, say, 1000 meters, and pasturage farther up.[4] In some Central

[1] "Each of the modern nations of Southeast Asia includes a nucleus of plains people who form, in each case, a relatively homogeneous and dense population. Each of these peoples speaks a single dominant language, is characterized by adherence to one of the world's great religions, and is subsistence based upon intensive 'wet rice' agriculture. But each of the countries also includes a minority of hill people, who are always far more heterogeneous. They speak a multitude of languages, have no political unity among themselves, and until the last century have never had more than tenuous political ties with the plains. The hill people usually practice shifting agriculture and have been much slower to become Buddhists, Hindus, or Muslims than have their neighbors on the plains." Robbins Burling, *Hill Farms and Padi Fields: Life in the Mainland Southeast Asia* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1965), p. 4. For a more dynamic approach which shows acculturation, see Ben J. Wallace, *Hill and Valley Farmers* (Cambridge, Mass., and London: Schenkman Publishing Company, 1970).

[4] "Agriculture is the principal activity of the residents of Uchucmarca [a village located east of the Marañon River in northern Peru]. Here, the Andes provide a complex mosaic of micro-environments within a limited radius. The Uchucmarquiños use land which ranges from 800 to 4300 meters in altitude. They divide this area into seven zones (moving from lowest to highest altitude) . . .

"*Temple* (1280–1500 meters in altitude). This is the lowest and hottest zone, the smallest in area and the most intensively cultivated. Irrigation accompanies all cultivation. The major crops are sugarcane, coca, maize, sweet potatoes and bananas. They are grown principally for cash sale.

"*Kichwa Fuerte* (1500–1900 meters). This is a steeply sloped zone which contains the least amount of level land. It is extremely susceptible to drought and because of this was largely abandoned between 1965 and 1970. Given sufficient rainfall, wheat and maize can be grown successfully, as can alfalfa for cattle feed. Some households specialize in raising guinea pigs (*cuyes*) and chickens for trade in the upper valley. Fairly dense stands of shrubs and trees provide firewood for the village.

"*Kichwa* (1900–2450 meters). Rainfall is more dependable here so there is no irrigation and both the amount of cultivable land and the size of plots are greater than in the two lower zones. This is the primary grain-producing zone. Major crops are wheat and maize; secondary crops are beans, alfalfa, maguey, barley and some fruits. Wheat grown in this zone is the single most important crop in the diet of the valley in terms of both calories and proteins.

"*Templado* (2450–2800 meters). This is an intermediate zone, sharing some characteristics with those above and below. It is marked by fairly steep slopes and hence a reduced area for cultivation. In the lower part of the zone wheat, maize, and barley are grown. In the upper part some varieties of potato, kidney beans and broad beans are grown. Two crops—*lentajas* (lentils) and *arvejas* (peas—a principal subsistence crop)—are grown only in this zone.

"*Jalka* (2800–3500 meters). This is the highest agricultural zone of the valley; above its limits the threat of frost is too constant. The valley widens here and the hillsides become less steep. Potatoes are the major crop. Other Andean tubers are also grown as are barley and broad beans. Some animals are pastured here.

"*Jalka Fuerte* (3500–4300 meters). The most important use of this zone is grazing of animals on communally owned pastures. These animals are kept largely for their natural increase, which is sold, rather than as sources of milk, cheese and meat. Sheep are also valued for their wool.

"*Ceja de Montaña* (2500 meter and below). The largest portion of this zone lies on the east side of the Andean *cordillera*. Heavy vegetation, rainfall, moisture, low soil fertility, and rugged terrain make cultivation virtually impossible. Lumber is cut here and wild animals are hunted. A limited amount of slash-and-burn agriculture (producing maize and beans) is practiced on the lower portions of this zone.

"It is difficult to state the number of regions in which the villagers have access to plots. The ideal, of course, is all seven. My impression is that almost every household has access to plots in an average of four to five zones—as owner, sharecropper, or day laborer whose wages are paid in the produce cultivated.

American countries, large-scale farmers may have cotton at sea level, corn a little higher, and coffee on the steeper slopes. In parts of China, hill land provided fuel and green manure for the rice farmer whose main fields were in the plain. In certain low-lying rice areas, which are liable to severe flooding, it is advantageous to have a small patch of higher land to use as a seed nursery, even though the two plots are not contiguous.[5] In Sri Lanka, comparative advantage for the export market was in coffee and later tea, both grown on hillsides.

4. Some hillsides are occupied by small-scale farmers because it is their historic legacy. The pattern of colonial settlement may have created a land tenure pattern of latifundia estates in the rich valley land which left the vast majority of those in agriculture in a marginal position. In order for residents to obtain subsistence, hillsides were the only possibility. In times when these estates were in danger of a rebellious group of nonowner peasants, the owners may have parceled out some of their hillsides in order to placate the land-hungry poor. If there had been a dynamic labor market (if, for example, unskilled labor was needed in cities), these mini-plot farmers would have sold out long ago. If there had been a dynamic land market, any large holdings not intensively farmed might be available to make better use of their labor source. When such is not the case—and in most less developed countries it has not been—historic patterns become congealed.[6] The origin of some upland farms is a temporarily improved urban labor market which caused landlords to give out some nearby, but marginal, plots to assure a seasonal labor supply at times of peak labor needs, like seeding and harvest.

Nadel has described the contemporary results of such a historic phenomenon in one setting:

> A Guatemalan *campesino* needs total concentration, all his ingenuity, to raise enough food for his family. The best land was long ago seized by the *latifundistos [sic]*, the landowners on the great plantations of the lowland and Pacific coast who grew coffee, bananas, and sugar. The Indians were forced into the mountains. They plant on slopes as steep as sixty-five degrees. Every year, there are Indians who fall to their death from the cornfields.[7]

5. Some farms in the tropics are located on hillsides because clearing of vegetation may be easier there than in the more humid valleys: fire usually burns more intensively and kills unwanted vegetation more surely there than on level land. Fire control there is often easier because fire only burns up a hill, never down, and tree trunks that are felled can be easily pushed down a slope and out of the way. Thus hill land farms may be sought out by those with little capital and having only fire power and brawn, regardless of the fertility of that land.[8]

Given the fact that more of the world is hilly than flat, it is rather remarkable that little direct attention has been given to the economics of hillside agriculture. That this will not be true over the long run is probably due to a number of interrelated reasons:

1. Population has been growing so rapidly that it necessitates the use of severely sloping land in some countries. Every ecological area seems to have its own problem related to soil conservation to which a certain amount of research has been given.[9] In some countries of East Asia, where population is particularly dense, the art of terracing developed with the growth of that population. In nations where population was not so dense, there was always another hill to move to, so that a conservation ethic did not develop. With the decline of the Inca Empire and the drop in Indian population in the Andes, the art of terracing was lost in the New World. In part of Nepal, terraces are now extremely necessary, but many have been constructed with an outward and not an inward slope, so the monsoon deluges

> It appears that the resources of land and labor are adequate for the village as a whole. There are, however, differences in resource distribution among households. Land and labor are distributed by a number of reciprocal relationships which are established primarily through kinship links. The most important of these is sharecropping, and others include exchange of labor and exchange of food."
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> Stephen Brush, "A Study of Subsistence Activities in Uchucmarca, Peru," *LTC Newsletter* no. 40 (April–June 1973), p. 10. See also Stephen Brush, "Subsistence Strategies and Vertical Ecology in an Andean Community: Uchucmarca, Peru," Ph.D. Diss. (Madison: University of Wisconsin, 1973); Emil Haney, *Possibilities for the Economic Reorganization of Minifundia in a Highland Region of Colombia*, Land Tenure Center Research Paper No. 43 (November 1971).

[5] Fragmentation may be a problem in farming patterns like this. See Sir Bernard O. Binns, "The Consolidation of Fragmented Agricultural Holdings," FAO Agricultural Studies No. 11 (Washington: United Nations Food and Agriculture Organization, 1950). As intimated in the last footnote, fragmentation is not always bad: the small pieces that are farmed may be intricately combined to allow a subsistence farmer to minimize his risk by taking advantage of different slope, soil, or even climate.

[6] No one who has observed the rebuilding of a community—whether rural or urban—after, say, a devastating earthquake or a raging flood, even when community members have full knowledge that such natural catastrophe is likely to occur again, ceases to marvel at the persistence of some settlement patterns.

[7] Gerry Nadel, "Guatemala," *The Atlantic Monthly* (July 1976), p. 19. A variant on this theme is provided by Mario Góngora, *Origen de los Inquilinos de Chile Central* (Santiago: Editorial Universitaria, 1960).

[8] Homer Aschmann, "Hillside Farms, Valley Ranches," *Landscape*, Winter 1955–56, pp. 18–24.

[9] See, for example, W. B. Manipura, "Soil Erosion and Conservation in Ceylon with Special Reference to Tea Land," *Tea Quarterly*, Vol. 42, No. 4, 1971, pp. 206–211.

weaken them more each year. And terracing isn't always the answer. Soil experts in the Uluguru mountains of Tanzania found that strategic tree planting and farming on the contour are better than terracing, which exposes too much infertile subsoil and encourages landslides.[10] Perhaps a good engineer would have solved the terracing problem in Tanzania, but even so, ways of conservation which work well in one area may not be as effective elsewhere.

The upper part of the northern temperate zone, which is the center of agricultural research and its dissemination, contributes few answers for the hill problems in the southern temperate or torrid zones. Since hills in the north temperate zone are relatively sparsely populated, new technology was developed for management of relatively flat land. The Alps and the Rockies were not subjected to attempts at intensive cultivation. From them, only transhumance was expected. This distinguishes them from the Andes, the Himalayas, and the Ethiopian Highlands, which have supported great civilizations and population pressures for generations.

2. Shifting cultivation (the most primitive kind of agriculture, but the type many observers feel conserves energy best) seems to be becoming more destructive. This is often also related to the population issue: fallow periods become shorter because the land must support more people. This type of farming may be briefly defined as an economy of which the main characteristics are rotation of fields rather than of crops; clearing by means of fire; absence of draft animals and manuring; use of human labor only, accompanied by a dibble stick or a hoe; and short periods of soil occupancy alternating with longer fallow periods. It is utilized in the humid tropics where plowing and cultivating the soil for row cropping would hasten biological activity such that organic matter would deteriorate and torrential rainfall would leach out what nutrients remained.

If shifting cultivators generally prefer flat land, it is increasingly becoming unavailable to them. In countries such as Taiwan, the Philippines, Indochina and Thailand, they have been forced back onto steep slopes; but while the tendency is probably most pronounced in Asia, it is also occurring in Africa and Latin America. Yields of burned-over plots tend to decline markedly after the first crop. When fertility declines, noxious grasses and weeds appear among the tree stumps, and predatory insects and other pests begin to multiply rapidly. If there is an abundance of forest land at his disposal, the shifting cultivator will prefer to abandon fields regularly because it is more efficient of his labor to do so (clearing is easier than weeding). Under favorable conditions, the pernicious grasses will give way to second-growth forests which will ultimately rebuild soil fertility. But with increasing population pressures, shifting cultivators are often returning to the old plot before a second-growth forest has adequately developed to recycle nutrients to the soil surface. Only a few of the original species may have returned. Repeated cultivations further impoverish the forest and reduce the number of species. Certain light-loving species which played only a minor role in the original climax forest may spread and dominate, together with those that show some resistance to fire. When the area is frequently returned to and burned over, there is no chance for it to revert to its original state; only grasses, herbs, and pyrophytes survive, and savanna emerges. Some of these triumphal species burn easily (excepting pyrophytes) and may be set on fire almost every year, thus deterring natural forest vegetation from returning.

Furthermore, this fire invades natural forests that have not yet been incorporated into shifting-cultivation agriculture. Once this growth has been changed from forest vegetation to grass, it is of no more use to the shifting cultivator and the only benefit he may get out of it is for hunting. For this he often uses fire also—to drive his prey out of hiding. The land can, of course, be used for grazing, but since the forage is poor, livestock carrying capacity is low, meat quality inferior and the cost of the end product high. At any rate, because substantial capital is needed to get into cattle farming, shifting cultivators seldom do it, preferring to transfer their tenure rights to ranchers at great cost to themselves and to society.

It is possible for an area to be left alone where rainfall is relatively ample and well distributed, and reforestation may recur. But currently, to use one example, more than 18% of the Philippines is covered with grass vegetation due to shifting cultivation. As population grows, the chances of forest rejuvenation become increasingly remote.[11] One recent source concludes: "[Shifting cultivation]" annually accounts for more felled trees than the spread of permanent agriculture. In Asia, for example, the FAO estimates that 8.5 million hectares of forest are cleared each year. An estimated five to ten million hectares are cleared annually for agriculture in Latin

[10] P. H. Temple, in *Studies of Soil Erosion and Sedimentation in Tanzania*, A. Rapp, L. Berry, P. H. Temple, eds. (University of Dar es Salaam, Bureau of Resource Assessment and Land Use Planning, and Dept. of Physical Geography, University of Uppsala, 1972), pp. 110–115.

[11] Karl J. Pelzer, *Pioneer Settlement in the Asiatic Tropics*. (New York: American Geographic Society, 1948). A balanced swidden system among the Tsembaga in New Guinea is examined in some detail in Roy A. Rappaport, "The Flow of Energy in an Agricultural Society," *Scientific American*, Vol. 224, No. 3, September 1971, pp. 117–132. For the system of shifting agriculture that the Tsembaga uses, it farms an area at below the carrying capacity of the soil.

America, mostly for temporary farming.[12] Pelzer speculates that the spread of grass due to population expansion in a small area may have been responsible for the downfall of the civilizations of the Khmers in Cambodia, the Mayas in Mexico and Central America, and the Sinhalese civilization centered at Anaradhapura.[13]

3. While everyone knows of the danger posed to human life and property by a flash flood, only recently have we come to recognize other close interconnections between the highlands and the valleys. In some cases, a benign moisture flow may carry needed minerals to the valley floor. But if the highlands are denuded by improper management, a much greater percentage of the precipitation runs off, carrying soil particles along. This can render fertile valleys unproductive by covering them with such materials as sand and gravel and creating meandering riverbeds. If upland moisture reserves dry up in the hills and mountains, there won't be enough humidity and ground water in the valleys. While 10% of the human population lives in the highlands, another 40% lives in the adjacent lowland areas, and their future is intimately bound to developments on the slopes and plateaus above.

One example of the close interdependence of hillsides and the surrounding valley is found in Nepal. Population growth there, according to Eckholm, is forcing farmers onto ever steeper slopes which are unfit for farming even with the complex system of terracing found there. Villagers roam farther and farther from home to gather the fodder and firewood they need. As they do, they remove the trees and ground cover needed to hold the soil of the Himalayas, the highest mountain range in the world, in place. Landslides are destroying more and more settlements and crops. Topsoil washes into India and Bangladesh, an export for which Nepal gets no foreign exchange. Some terraces are maintained; others merely form the shells of abandoned fields. A 1967 government of India study cited by Eckholm estimates that in the country's most densely populated area, the eastern hills, as much as 38% of the total land area consists of abandoned fields. Erosion is the chief problem, but the declining fertility of the hills stems from another problem: the scarcity of animal manure which, prior to the contemporary period, the Nepalese have always assiduously applied to their fields. Now, when dung is available, it must increasingly be used for fuel; wood is increasingly far away. Also, there is less manure available because herd size is not growing, since hillsides must be used for field crops. The Nepalese hills must now support 22 people per ha, roughly the man-to-land ratio of Java or Bangladesh, countries blessed with far better resources.

Eckholm notes that "if Nepal's borders ended at the base of the Himalayan foothills, the country would now be in the throes of a total economic and ecological collapse. Luckily the borders extend farther south to include a strip of relatively unexploited plains known as the Terai, which is an extension of the productive Indo-Gangetic Plain of northern India."[14] He notes that this region suffers seasonal flooding, is heavily vegetated, and was historically plagued with malaria. With malaria eradication, there was a rush to colonize the area. In the 1964 to 1974 decade, 31 200 ha of Terai forest land was officially distributed by the government to settlers, but more than three times that amount was illegally cleared by migrants from the hills and, perhaps more significantly, from India. The Terai provides some reprieve for Nepal, but there seems to be no end to the problem. Satellite reconaissance indicates that there is another 111 750 ha that might be suitable for settlement; but if migration continues at present rates, the land will be filled in another decade. Meanwhile, something must be done about the hills which are causing the problem—especially since degradation of the mountains is causing rivers to swell and is cutting away at the fertility of the Terai. Nepalese government sources, reported by Eckholm, show Terai rivers rising at from 15 cm to 30 cm each year, probably because of stream-bed silting. This is causing rivers to wander about aimlessly, taking prime farmland as they go. The Nepalese National Planning Commission fears that the situation is almost at a point of no return, and feels that the hilly regions may develop into a semi-desert environment if nothing is done. Should the situation be allowed to continue along its present course, a predicament may exist in Nepal (and in Northern India and Northern Pakistan, for that matter) like that in most of Afghanistan and by the barren Zagros and Elburz mountains farther west in Iran.[15]

4. Closely related to the former point is the explicit problem of the disappearing forest, which not only is relied upon to hold upland soils in place, but to maintain the hydrological cycle intact and provide lumber and firewood. Once tree cover is cut, average temperatures in the area may rise and already arid soils not far distant may become desertic.

[12] Erik P. Eckholm, *Losing Ground: Environmental Stress and World Food Prospects* (W. W. Norton and Co., Inc., for Worldwatch Institute, 1976), p. 42.

[13] Pelzer, *Pioneer Settlement*.

[14] Erik P. Eckholm, "The Deterioration of Mountain Environments," *Science*, 189, (September 5, 1975): pp. 764–765. See also Claire Sterling, "Nepal," *The Atlantic Monthly* (October 1976), pp. 14–25.

[15] Eckholm, "The Deterioration of Mountain Environments."

Eckholm states it well:

> Forests influence the wind, temperature, humidity, soil, and water in ways often discovered only after the trees are cut, and these functions—usually beneficial to people—are sabotaged. Forests assist in the global recycling of water, oxygen, carbon, and nitrogen—and without any expenditure of irreplaceable fossil fuels. Rainwater falling on tree-covered land tends to soak into the ground rather than to run off; erosion and flooding are thus reduced, and more water is likely to seep into underground pools and springs.[16]

Then there is the problem of adequate lumber and firewood:

> Peasants in the uplands of South Korea have adopted a different, but also destructive way to cope with the lumber shortage. A United Nations forestry team visiting [Korea] in the late 1960's found not only that live tree branches, shrubs, seedlings, and grasses were cut for fuel; worse, many hillsides were raked clean of all leaves, litter and bramble materials. Raking in this fashion, to meet the needs for home fuel and farm compost, robs the soil of both a protective cover and organic matter, and the practice was cited by the UN experts as 'one of the principal causes of soil erosion in Korea.'[17]

5. Land reforms are becoming somewhat more commonplace than previously and can be expected to open up more land which in more pristine days was tied up in large estates. Where peasants could gather only firewood before, they are in some areas able now to have small farms of their own and cultivate them pretty much as they see fit.

With land reform must come some basic ideas of conservation. Here, China may provide an example. At one time half of its territory was forested. By the time of the new government in 1949, it was said to have the greatest number of barren hills in the world; rehabilitating most of them is entirely beyond the realm of possibility:

> In the 1950's, ambitious though probably unrealistic plans were made for mass reforestation, to be implemented mainly by the rural communes. The leadership hoped to raise the forested area to 20 percent of the country by the late 1960's, and 25 percent by the 1980's . . .
>
> Tens of millions of workers have since been mobilized to plant trees each year in the slack seasons between crop harvesting and sowing. The effort has been stupendous, though the results have sometimes been disappointing. By 1973, according to Chinese officials, about seventy million hectares—nearly 7 percent of the country—had been replanted, but in many areas the survival rate of the newly planted trees was, in this early period, below 10 percent. Untrained labor, poor maintenance, mutilation or even uprooting of newly-planted trees for fuel, and frequently inhospitable growing conditions combined to corrode the efficiency of the mass planting efforts. By the mid-sixties, official emphasis had been shifted away from massive annual new plantings to careful maintenance within planted areas.[18]

Just because a field is located in the mountains is no indication that its use will involve hillside farming, just as valley areas may well require at least modest conservation techniques. Some highland plains in the torrid zone have been centers of thriving civilizations, especially in days before men had learned to cope with either the seasonal extremes of the temperate zones or the exigencies of the humid tropics.

In Wisconsin, a 10–12% slope is considered suitable for row-crop farming only one year in five, and then with the strictest of soil conservation practices such as contour farming and terracing. To prevent water erosion the U.S. Soil Conservation Service recommends approved practices for slopes over 2%, and those over 12% are almost never put to row crops.[19]

But Wisconsin, with about 34 persons per square kilometer, and the United States, with about 23, do not need to use land that is exceptionally steep; better put, it makes no economic sense to do so. On the other hand, countries such as India (173 persons per square kilometer), Pakistan (121), Nepal (80), Japan (289), Nigeria (61), and the Philippines (130), to use some examples, must farm slopes that are far steeper and often less fertile than those in the United States Midwest.

Many of the most densely populated areas of the world are also those with a precipitation pattern that makes hillside farming especially difficult. Wisconsin can expect somewhat over 760 millimeters of precipitation per year, but some areas of the world can expect up to 10 200 mm and some of these have, in turn, a six-month dry period. Imagining the consequences of a 50 mm daily rainfall on a steep hill where there is dense settlement gives one an idea of the difficulties facing those who are responsible for conserving soil resources to at least assure minimal subsistence.

[16] Eckholm, *Losing Ground*, p. 27.

[17] Ibid., pp. 105–106.

[18] Ibid., p. 44. See also Sterling Wortman, "Agriculture in China," *Scientific American*, Vol. 232, No. 6, June 1975 and W. C. Lowdermilk, *Conquest of the Land Through Seven Thousand Years*, Agriculture Information Bulletin No. 99, USDA Soil Conservation Service, undated, cited in Don Schwennesen, "The Environmental Beat," *Montana Journalism Review*, No. 19, 1976, p. 55.

[19] Personal conversation with James Enlow, U.S. Soil Conservation Service, Madison, Wis., July 15, 1976, and USDA, SCS, *What Is a Farm Conservation Plan?*, PA-629, Leaflet 249 (January 1973). See the Japanese perspective in Fukuo Ueno, "Problems in the Agricultural Utilization of Sloping Land," *Rural Economic Problems* 1 (November 1964): pp. 22–36.

It is technically possible to farm the steepest of slopes. In most of the United States it is not economically justifiable to do so, though scarcity of food in the rest of the world may change the situation radically in the long run. In the wet zone of Sri Lanka, I have seen a fruit crop adaptable to poor soil, grown on a 75% slope, using stones for terracing hauled—one by one and by human brawn alone—from the valley below. In some rice areas of East Asia, not only the terracing rock but also the topsoil have been hauled up the steep gradient to form a 2% mini-field from a 90% slope. But the effort required technical expertise, community cooperation and organization and capital. Indeed, whether hillsides can be saved seems to depend more on the will of the people to do so, on food to sustain the workers while they are terracing and on wise technical help, than on steepness of slope, amount of rainfall concentrated in a period of time and population density. Many areas in Japan and China do an exceptional job against formidable odds. This seems to teach us that the solution to the problem depends as much or more on social organization and on economics than on a new technology. For the most part, the technology of saving soil exists; when it is not applied, what is almost invariably lacking is an appropriate combination of economic incentives and opportunities for doing so. The case is the classic one of physical and biological expertise being highly developed in comparison to the politics and economics of the situation, which do not translate expertise into human action. There are alternative ways of farming any piece of agricultural land that provide maximum immediate yield, that maintain potential for future production or that satisfy a combination of these two goals. When people choose alternatives that allow their only means of livelihood literally to wash from under their feet, the personal characteristics or traits of those who make the choice ("indolence" or "stupidity" or "sloth") are often cited as a reason. Much more plausible are explanations that rest on land tenure rights and custom, together with the accompanying system of lack of incentives, barriers to the spread of technical information and tradition, which they imply and about which we understand so little. It may be perfectly rational for peasants to make little effort to engage in long-term investments of contour farming, terracing, tree planting etc., for they know that once land is improved it will revert to another, perhaps a landlord. Or maybe they simply do not have financing for this long-term investment. If the hillsides of the world are to be saved, such problems as monopolistic control of land and short-term leasing will have to be dealt with explicitly. And when agrarian reform becomes an accomplished fact, conservation techniques won't simply come naturally to beneficiaries. New owners must be suffused with an ecological ethic as well as with the technical knowledge which has for so long been the domain of a few who have the wherewithal to use it.

What agricultural laborer with a year-to-year lease on a farm will go to great lengths to save hillside soil if he knows that his back-breaking efforts at terracing will merely conserve the resource for the landowner, who may dispossess him as soon as his laborious work is complete? What squatter will practice contour farming or reforestation if his occupancy rights are so tenuous that it is cheaper for him to move on to another hillside patch next year (and by moving he may be less visible besides)? How many hillside farmers will be able to afford the time and money necessary to terrace if they own a mini-plot on hilly terrain and rely for the bulk of their incomes on work for large valley farmers below?

And, in an area of freehold mini-plot farming, the issue is somewhat different—having to do with organization, esprit de corps in the neighborhood and leadership. What small-plot owner on the hillside can afford terraced farming (and what is its efficacy, anyhow?) if he alone wishes to practice it while his neighbors do not? How many soil-conservation experts are there who are available to work with, say, 500 small farmers who crowd onto one 10-hectare hillside on which the minimal slope is 25%?

The issue also centers upon education or, at least, on effective transmission of technical information. How much does a recent beneficiary of a land reform know about row cropping on slopes, something that he may now have to do to earn his living, when prior to the reform he saw it used only for grazing? How much does he know about reforesting land that his former landlord left barren?

The emphasis of this volume is on new technical information that will help save the hillsides; this is to be applauded. But what is even more important for millions of the world's peasants—the bulk of those who are engaged in agriculture in all less developed countries—is using what is now known about soil conservation. And what is now known and what is yet to be discovered will not be applied if the social, political and economic organization is not appropriate for the task. From this observation one could extrapolate many policy implications, but I will list only five.

1. If the legal framework were in place to assure a tenant who invests in terraces, contours or forests that he could retain the land after certain minimal conservation standards were met (or at the very least that he could retain it for the number of years required to attain a respectable rate of return—which would probably have to be the lifetime of the cultivator), he might do so.

2. If hillside squatters' tenure rights could be made secure, they might be more apt than otherwise to attempt conservation practices.

3. If hillside-farmer organizations could be set up, conservation and grass-roots leadership potential could be developed if incentives were provided. Of course, governments will also have to be committed, at the very least, to providing subsistence for workers while they are constructing terraces or planting trees.

4. If soil conservation techniques were made as important as the seeds and fertilizer that are available as part of the package of inputs that follow up a land reform, steeper gradients might be saved.

5. If zoning procedures could be set up so that industry and transportation systems would have to use the unproductive hillsides and the basins were reserved for agriculture, several generations of time might be bought to allow for the rapid rate of population growth to be curtailed. A certain amount of government intervention and even subsidy would be involved, since short-term private establishment costs would be raised over what they might be otherwise, in exchange for long-term benefits to the nation.[20]

The price of negligence is desolation of both hillsides and valleys, increased influx into the already glutted cities, and human degradation and starvation. In controlling the contemporary over-rapid population growth and rationalizing the presently chaotic way in which available land is used, the ultimate problem with which humanity must deal is how to achieve an appropriate balance between man and land.

I close this paper as I opened it with a quotation for emphasis from Erik Eckholm's *Losing Ground*:

> Land-use patterns are an expression of deep political, economic, and cultural structures; they do not change overnight when an ecologist or forester sounds the alarm that a country is losing its resource base. In many countries, the deterioration of the land will not be halted until basic changes in land tenure and national economic priorities occur.

DISCUSSION

Marva Browne (West Virginia, USA). Please comment on how trade and tariff barriers and economic factors affect hill land farming on an international basis.

[20]This suggestion is one of those that Bryant Kearl made upon reading a draft of this paper.

Thiesenhusen. Well, I know that removing some of the tariff barriers facilitating trade has been one of the demands of the third and fourth world. The idea presumably is that by removing some of these barriers, allowing more trade, one improves the lot of the third and fourth world countries. I am a bit concerned about this from the standpoint of the countries we're talking about. But, first of all, export crops, with some exceptions, are owned by a rather small elite in the countries we're talking about so that much of the export earnings will go to this very small elite and will not really serve to broaden the base of the economies of the third and fourth world. Secondly, if we're talking about hill land, it is a general, but no means universal, pattern that hill lands grow subsistence crops. We heard earlier, for example, that sugarcane is grown in the low lands, sugarcane is used for export, yam and potatoes are grown on the upland. In general, if we increase trade, we are increasing the income of those who farm the flat lands and we're really doing very little for those who farm the hills; there are exceptions, of course. These are a couple of reasons why I worry a little bit about those who say that the economic position of the third and fourth world would be helped a great deal by promoting trade. There will be some spread effects, perhaps, in marginal areas of the country but, by and large, promoting trade will benefit the elite, will benefit those who farm in the plains and this will have some spread effect to the hillsides, but the effect will be rather limited.

Browne. I understand what you're saying and I realize this is just one aspect of the big problem of assisting people in development, but it is one of the areas that's been receiving attention and since there is a move to more land reform in some areas it wouldn't necessarily benefit only the elite, it still would help somewhat other countries.

Thiesenhusen. Oh yes, I'm not saying that things are absolute. Professor Breimyer also has a comment here.

H. F. Breimyer (Missouri, USA). This is Bill's area and not mine but he responded accurately in terms of trade and farm products; so much of it favors the elite. But the other side of it is of course the industrial products of countries that have labor intensive industry where I have felt that the reluctance of industrial countries of the world to allow imports of labor intensive products such as Indian textiles, has been a handicap in world food trade; that India could buy more wheat for her city people if we would buy her textiles whereas we actually put a quota on them. But I don't know what the magnitude is—I don't think it's terribly great. Dr. Thiesenhusen would know better than I.

Thiesenhusen. Well, I don't know better than you. I just know that it's simply not that great, but let

me respond in this way: a goal of land reform should be to increase labor intensive products, whether we're talking about industry or agriculture, and if in land reform we get more labor intensivity, this is what we're shooting for. After a land reform, trade may be much more useful, much more beneficial than it is today. When I answered the original question, I was answering it only on the basis of the current socio-political institutional structure.

45.
Crop Production on Hill Lands: Has the Small Farmer Been Bypassed?

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Hill land agriculture occurs from sea level to the limits of plant growth imposed by low temperatures at higher elevations. Steep slopes, however, seldom sustain the degree of cropping, grazing and wood-cutting as encountered in level or undulating areas. Rainfall, degree of slope and erodible soils impose constraints on crop production at all altitudes. At higher elevations ecosystems become more fragile (Eckholm, 1975) and reduced temperatures, varied microclimates, orientations of slope to the sun and prevailing winds restrict cropping systems. In addition, lack of animal power, shortages of animal feed and limited compost lead to lower crop yields than on low-lying farmlands. Isolation, inadequate transportation, restricted markets and lack of services also contribute to subsistence farming or other less profitable farming systems. Small holders at higher elevations tend to have less income, less education, and less political influence than those at lower elevations and in the valleys (Eckholm, 1975). Despite the ascribed characteristic of being "passive" (Whyte, 1975), however, they have generally developed traditional farming systems considered to be effective and efficient given the limited resources under which they must operate.

The purpose of this paper is to:

(1). Review the effect of altitude on crop adaptation.

(2). Characterize hill land agriculture.

(3). Describe variations in farming systems and cropping patterns.

(4). Examine productivity of hill and flat lands.

(5). Outline means of increasing crop production.

(6). Discuss approaches to improving cropping systems.

ALTITUDE AND CROP ADAPTATION

The effect of elevation on native or naturalized vegetation is vividly portrayed as one moves from low lands to the upper limits of alpine meadows. Changes in types of crops grown may be less dramatic because of the strong intervention of man. One expects to see, however, different crops growing at different elevations. For example, a vertical land use profile in Ecuador depicted rice, maize, tobacco, sugarcane, bananas and cocoa from sea level up to about 500 m elevation, with coffee, bananas, sugarcane, and maize occurring to about 2 000 m. Potatoes, small grains (wheat, barley, oats) and maize extended beyond the frost line and approached 4 000 m in some localities (Sick, 1963). With crops such as maize different varieties are found at various elevations. Altitude shows a marked influence on plant growth and development, and length of the growing season, largely due to temperature effect. Maize, which can be harvested within three months after planting in the hot lowland regions, may take from 10 to 12 months to mature at 2 500 to 2 800 m and up to 15 months at 3 500 m in the Andean region.

In the tropics potatoes are generally grown in highlands (Thurston and French, 1972). They are not produced commercially much below 1 700 m in the Colombian Andes. Plantings occur as low as 1 000 m, but yields are low and returns uneconomic. In Peru extensive production under irrigation is found near sea level where the Humboldt Current has a cooling effect. Bacterial wilt is a limiting factor at low elevations and the disease becomes more serious as the temperature increases. A temperature range of 25–36° C appears optimum for bacterial wilt development in potatoes, and below 13° C the disease

is inhibited. On the tubers the disease is manifested as a brown rot and was first noted in an isolated area near 2000 m in Peru. Within three years it had spread to varying elevations through the indiscriminate use of infected tubers as seed. The disease was less evident at higher altitudes and at 3200 m or beyond no symptoms were expressed. When tubers from plants known to be infected were planted at lower elevations the disease reappeared, showing that they were carriers of the causal organism.

CHARACTERIZATION OF HILL LAND FARMING

Hill agriculture may be characterized by (1) a production system which has become so intensified that resources have become limiting and (2) a farming system which provides most of the family needs (Rockefeller Foundation, 1976). The first condition refers to the "tightness" of the production system and reflects resource limitations such as small farm size and fragmentation of landholding, inadequate power for tillage, a shortage of grazing land and animal feed, infertile and eroded soil, insufficient compost, uncertainty of rainfall, few alternatives in terms of cropping patterns, seasonal shortage of labor and scarcity of firewood. The second characteristic is largely that of a non-market or limited-market economy. Without access to markets most farms operate at a subsistence level, producing most of the family food needs and a high percentage of materials needed for warmth and shelter.

Nepal typifies this situation where 1 ha of arable hill land must support at least nine people (Eckholm, 1975). Here the forces of ecological degradation have wrought dramatic and visible changes in a short period of time with little prospect of favorable recourse in the near future. Population growth has compelled crop expansion onto steeper slopes, placing greater pressure on grazing lands. Animals now graze over wider areas so that manure which is collected for compost or fuel must be carried a full day back to the village. Villagers roam farther and farther to collect fodder and firewood. In some regions one member of the family spends an entire day gathering 30–40 kg of fodder tree branches and leaves as contrasted to three or four hours ten years ago. Grasslands and forests are rapidly deteriorating and disappearing. This leads to heavy erosion on denuded slopes and landslides which destroy lives, homes and crops. In addition to increased natural erosion, soil fertility decline is hastened because of a limited supply of compost made from organic residues and manure. The ever-widening circle of tree destruction, forest deterioration, increased use of residues as animal feed and burning of dung limits materials for composting. As land productivity decreases fields are sometimes abandoned, even as the demand for food increases.

Comparable situations exist in other hill and mountain regions. In India, Pakistan and Afghanistan cultivation is constantly pushed farther up the slopes, thus advancing the spread of grazing goats and sheep. In many regions no topsoil remains, leaving outcrops of rock substratum with a thin growth of scrub plants and low quality grass and herbs. For many years dung has served as fuel or if composted has been spread over the more fertile fields. Overgrazing and overcropping in the Andes have depleted soil fertility and vegetation, aggravated soil erosion and reduced animal and crop production (Eckholm, 1975). In the more densely populated areas of Peru and Bolivia, such as the Lake Titicaca Basin, from ½ to 2 ha of infertile land sustains an entire family. The highlands of East Africa present a similar picture, as noted in some regions of Ethiopia where steeper slopes no longer support grass or shrubs and in others where farmers have recently begun to bring reserve grazing lands under cultivation. Increased animal pressure on remaining grazing lands results in further overgrazing, decline in herbage yields, lower conception rate of livestock and thereby reduced cattle population. Fewer livestock means less compost available for the increased cultivated land. Crop yields further decrease, creating a greater need for more arable land, and necessitating use of additional grazing lands: a seemingly never-ending cycle.

Another factor of dire consequence is that the small holder, especially in the hill lands, has been bypassed or only marginally touched by the benefits of modern agricultural technology. He has been described as passive, steeped in traditionalism, having low aspirational levels and a fatalistic attitude, lacking innovativeness and being opposed to change, displaying limited time perspective, showing hostility toward government and distrust of all who interfere with his personal life (Rogers, 1969). It is only in recent years that studies focused on the subsistence level and geared toward an understanding of the real situation have modified our vantage point and that of the peasant farmer (Castillo, 1975; Whyte, 1975). In general, these "bypassed" farmers do not know what they can do other than their current practices, lack the capability to adopt new technology, or do not have the physical resources to justify investment in more risky practices.

VARIATIONS IN FARMING SYSTEMS AND CROPPING PATTERNS

The farming system includes integrated farm operations based on land resources, farm enterprises and available technology to produce agricultural commodities. To this has sometimes been added the interaction with off-farm social and economic envi-

ronments (Rockefeller Foundation, 1976). Definitions vary with the myriad classifications and descriptions of farming systems around the globe. The different systems form a continuum from traditional shifting agriculture and transitional permanent cultivation, through mixed farming, large-scale farms and plantation crops, specialized horticultural farming to livestock ranching and intensive livestock production (Allan, 1965; Benneh, 1972; Conklin, 1961; De Schlippe, 1956; Duckham and Masefield, 1970; Evenson *et al.*, 1973; Greenland, 1974; Grigg, 1970; Manshard, 1974; Netting, 1968; Okigbo and Greenland, 1976; Parsons, 1970; Ruthenberg, 1971; Spencer, 1966; Watters, 1971; Westphal, 1975). It is beyond the scope of this paper to review the various systems. Instead, a generalized model of hill farming in Nepal (Figure 1) is presented to show a few of the major interactions among arable croplands, grazing lands, livestock and forests (Rockefeller Foundation, 1976). Systems vary within and across physical

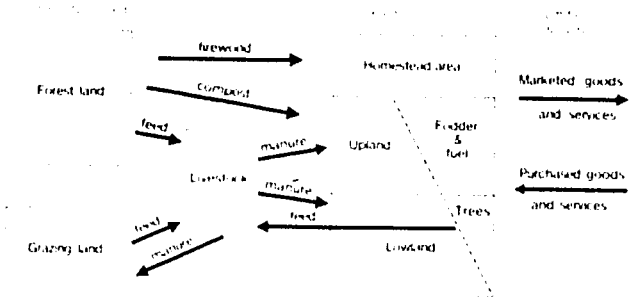

Figure 1. Conceptual model of a farm production system in the hill lands of Nepal (redrawn from Rockefeller Foundation, 1976; original proposed by R. R. Harwood and D. E. Welch).

environments based on resources available to the farmer and his family needs. A cropped area (sometimes less than 1 ha) exists around the homestead and another small field lies at some distance away. The combination of both upland and lowland fields allows for considerable diversity in terms of crops grown. These areas provide the family staple food and oil needs and may produce a small surplus. Fodder and fuel trees around the home site and along field boundaries and pathways provide animal feed. The crop area receives nutrients from leguminous crops, the grazing lands or forest area either as compost or plant residues. A number of field and vegetable crops are grown, usually in diverse and mixed cropping patterns. At lower elevations it is not uncommon to find 40 to 50 plant species for food purposes on a single farm. At higher elevations, where slower plant growth limits productivity, no more than 12 to 15 species may be used. Crop residues provide additional feedstuffs for livestock.

Grazing lands are communal with no restrictions on the number of animals a single family may herd and no limitation on the extent of grazing. Overgrazing is a common practice and no one expresses interest or assumes leadership in grassland improvement or grazing management. The grazing area provides nutrients (usually of low quality) for livestock and receives nutrients from animal excretion. In many areas grazing lands on steeper slopes have been brought into cultivation.

Livestock provide power for land tillage, compost for the crop area, dung for fuel, hides and food products, and serve as beasts of burden. They are usually stabled on the homestead and fed crop residues, hay from wastelands, fodder from trees and shrubs, or grazed communally, thus requiring considerable labor for care and maintenance.

Forest lands are communal property and provide firewood, feed and bedding for livestock, compost for direct use on crops, construction material and medicinal herbs. They receive little or no input from the farm operation and in many areas are in a state of decline and deterioration.

Most Nepalese hill farmers are isolated by several or many walking days to the nearest market. Without inexpensive transportation and available markets, subsistence farm operations are likely to continue and their improvement undoubtedly will remain a high national priority. Seasonal migration, and to some extent permanent movement, into the recently developed lowland plains (Terai) provides temporary relief for the hill lands but does not offer an adequate solution to the pressures of an expanding population and the increasing need for food.

PRODUCTIVITY OF HILL AND FLAT LANDS

General observations strongly suggest that crops on hill lands yield less than those on flat lands and valley terrain. At Sontecomapán in the state of Veracruz, Mexico, yields of unfertilized maize grown on cultivated lowlands for 17 years dropped from about 6000 to 4000 kg/ha. On 15% slopes production declined more rapidly and farmers were forced to shift to new fields after four years. On 20% slope near Lake Catemaco severe gully erosion occurred after three years of cultivation (Watters, 1971), indicating that a shorter cropping period should have been practiced.

In Colombia, rice growers have consistently obtained yields of five tons/ha or more since 1970 on irrigated flatlands (Noti-CIAT, 1975). Upland rice production is a different system in which production is generally determined by the weather. If rainfall is sufficient, and occurs when needed, upland rice may yield over two tons per hectare. A similar situation exists in the Philippines where the family life of hill land and mountain farmers revolves around one annual crop of rice. The one-ha farm

produces 1.0 to 1.5 tons of paddy rice, most consumed by the average family of eight. Rice farmers in these regions have been bypassed since no new technology has been developed which is applicable to their situation (IRRI, 1975).

In a study which describes the structure and organization of agriculture at a farm unit level in the Bajio Central Tableland of Mexico, Gonzalez and Silos (1968) noted some striking differences between hill and flat land agriculture. They examined so-called large and small farm operations of 30 ha or more and 30 ha or less, respectively, under pump irrigation and natural rainfall conditions, the latter in flat and hilly terrain. Crops under irrigation consisted of wheat, maize, alfalfa, tomatoes, garlic, onions, beans, chick peas and others to total 15 on large and 12 on small farms. Under rainfed flat and hill land conditions maize, maize-beans and chick peas were grown. Yield indices (Yield index = ha needed to produce average regional yields/number of hectare sampled) of 109 and 91% were obtained on large and small irrigated farms, respectively, 48% on rainfed flat land, and 40% on rainfed hill land farms. Land use indices expressed as hectare-months of cultivation showed 69 and 65% for the large and small irrigated farms, respectively, and 49% for both rainfed farm types. A portion of the irrigated land was double cropped, but the rainfed land was cropped only once during the year. Drought and root worms caused a 15 to 20% loss of planted cropland on rainfed farms.

Irrigated farms were more highly commercialized than rainfed farms. Farm products marketed from large and small irrigated holdings were 90 and 80%, respectively. Those marketed from large and small rainfed farms were 70 and 53%, respectively, but only 40% from the hill farms. Calculation of the agricultural production value showed both types of irrigated lands to be ten times higher than the rainfed flat lands and twenty times higher than rainfed hill lands.

These data augured strongly in favor of irrigation but most importantly pointed to the benefits gained from utilization of available resources. The study showed that larger farmers with irrigation facilities rented additional land area which could be irrigated. On the other hand, an increase in farm size of rainfed flat land led to increased sharecropping. It was emphasized that farms under seasonal rainfall tended to operate at a subsistence level, especially in the upland area, with a large number being outside of market channels and their operators having low purchasing power.

INCREASING CROP PRODUCTION

Crop production can be increased by expanding the area under cultivation, increasing yields/ha of a given crop and increasing total production/ha by multiple cropping.

Area Under Cultivation

Approximately 11% of the earth's land surface is used for arable crops and 22.3% is devoted to permanent meadows and pastures (FAO, 1974). That designated as arable reflects about a 0.2% increase during the past ten years and almost a 1.0% increase since the early 1950s. Not all of the 11% recorded as arable is cropped annually because of shifting agriculture. Brown (1963) estimated that 7.6% was actually cultivated because of different types of fallow. For example, in the Central Africa Republic a figure of 5.8 million ha of arable land was reported in the 1964 FAO Production Yearbook, but 3.0 million were listed as being in fallow.

Over the years expansion of arable land has been the main source of increased food production. The proportion of land used for crops varies among regions, ranging from 5.0 to 5.8% in South America, Oceania and Africa, 12.2 in North and Central America, 13.2 in China, to 17.3 in Asia and 29.0 in Europe. Robertson (1956) estimated that arable land in Europe, USSR, and the European-settled areas overseas, which accounted for 48% of the earth's arable land in 1953, expanded by about 90% between 1870 and 1950. Pawley (1963) calculated the world's area devoted to cereal production in 1960 to be 30% above that of 1913 and 18% above that of 1939. Data in Table 1 show the expansion of land area under cereal crops (wheat, rye, oats, barley, maize, millet, sorghum, paddy rice) since 1948-52. An increase of about 20% occurred on a worldwide basis, with a decline in Europe and a dramatic expansion in Oceania and South America.

Estimates of the total potential arable land range from about 11 to 30% (Grigg, 1970), but few reports

TABLE 1. Change of land area under cereals (FAO Production Yearbook 1964, 1974)

Region	Area, ha 10^6 1948-52[a]	Change, % 1963-64[b]	Change, % 1973-74
Europe	74.8	−6.5	−4.5
North and Central America	100.9	+6.9	−0.3
South America	20.4	+0.4	+77.9
Near East	22.7	+39.2	+58.8
Far East	132.0	+18.9	+23.2
Africa	45.0	+15.3	+51.2
Oceania	6.2	+50.0	+106.0
World	610.1	+10.4	+20.3

[a]Average of four years.
[b]Percent change based on area in 1948-52.

suggest where such areas exist. Revelle (1976) suggested that the potential gross cropped area could be more than tripled by including land under temporary fallow, temporary meadows for mowing and pastures, rubber plantations, as well as marginal lands which could be drained, irrigated or improved by fertilizer inputs.

Increased Yields of Single Crops

The spectacular increase in yields of singly grown crops has been widely demonstrated, especially since the advent of technological packages which include improved varieties, higher rates of fertilizer, use of pesticides and herbicides, timely tillage, adoption of soil conservation and water control practices. Wheat production in England will illustrate this dramatic transformation (Bennett, 1935). For almost 400 years yields hovered around 8-9 bushels/acre (approximately 0.53 to 0.60 tons/ha). During the seventeenth century harvests began to improve, corresponding to the advance of the Industrial Revolution, but more importantly being fostered by crop rotations in which a clover was included. Since that time modern agricultural technology added a number of other beneficial practices so that present yields often exceed 3.0 tons/ha.

Gains in crop yields have been derived from application of improved practices on the better land. Future emphasis should still be placed on the more fertile, well-drained, easily tillable soils rather than on steeper slopes which require greater inputs.

Notable gaps exist between crop yields in developed and developing countries, but more striking are the differences between the best and average farmers. In India and Pakistan the top 10% farmers obtain crop yields seven times greater than the average farmer, whereas in Pennsylvania the ratio is less than two (Pasto, 1961).

Multiple Cropping

The growing of more than one crop on the same land in one year is known as multiple cropping (Andrews and Kassam, 1975; Dalrymple, 1971; Harwood, 1974; Ruthenberg, 1971). It includes mixed cropping—two or more crops grown simultaneously and intermingled; intercropping—two or more crops grown simultaneously in adjacent rows; relay cropping—two or more crops in sequence, seeding or transplanting the succeeding one before harvest but after flowering of the former; double cropping—two crops grown in sequence, seeding or transplanting one after the harvest of another; ratoon cropping—taking more than one harvest from a single planted crop.

Multiple cropping evolved over the centuries under farming conditions of limited land resources and where increased population pressures imposed a need for more intensive farming systems. Mixed and intercropping are common practices of farmers classified as traditional agriculturists, particularly in developing countries. Some views of multiple cropping include:

Advantages. Increased total yield in terms of land equivalency (yield ratio of associated crops relative to their yields in pure stands); better utilization of environment, space and time; prolonged ground cover; greater distribution of labor; security against crop failure; minimized loss due to diseases, insects and other pests.

Disadvantages. Mechanization more difficult; application of inputs more complex; experimentation more complicated. (Andrews, 1975; Andrews and Kassam, 1975; Dalrymple, 1971; Harwood, 1974; Norman, 1974; Trenbath, 1974; Willey and Osiru, 1972).

Multiple cropping provides diversity in cropping patterns, constitutes a form of crop intensification, provides a more steady and a wider variety of foods than single cropping and tends to stabilize the farming system (Harwood, 1974). A high percentage of crops in developing countries are grown in associations: for example, 90% of the cowpeas of Africa; 90, 80, and 73% of the beans in Colombia, Brazil, and Guatemala, respectively; and 60% of the maize in Latin America (Francis *et al.*, 1976). Cultivars used by farmers who practice multiple cropping, however, are generally not available commercially but have been locally selected over generations to fit a particular cropping system. In fact, those selected and tested under conditions of a monoculture may not be suited for multiple cropping (Francis *et al.*, 1976) and little is known regarding the selection of plant types for growing in mixtures. Research directed toward multiple cropping and farming systems is somewhat limited and the interrelationships of crop associations have not been clearly sorted out. Yield increases from none to more than 50% have been obtained by growing two crops together. In general, studies have been conducted on the more easily tillable terrain rather than on steeper slopes (Aiyer, 1949; Andrews, 1975; Dalrymple, 1971; Finley, 1974; Francis *et al.*, 1976; Greenland, 1975; Grimes, 1963; Harwood, 1974; Kanwar, 1970; Kung, 1969; Norman, 1974; Okigbo and Greenland, 1976; Swaminathan, 1976; Waugh, 1975; Willey and Osiru, 1972).

IMPROVING CROPPING SYSTEMS

There is no assurance that technology gained from modern agricultural research is applicable to the small holders in hill lands. Most research findings, regardless of goals, better fit the practices of progressive farmers than those of subsistence farmers. Exceptions to this would be the use of high yielding rice and wheat varieties in several countries (Castillo,

1975; Dalrymple, 1975) and to some extent maize varieties. Even so, it has been the small holders in low lands who adopted the new varieties and made use of the associated technology package rather than those in hill lands. New varieties have not been bred to withstand the strong acid, low phosphorus, droughty soils, and highly variable temperature conditions so common in hill lands. Improved varieties, however, constitute the basis of technological packages and often are the component most attractive to farmers.

A valid criticism of the modern approach to improve agriculture for small holders might be the procedure used to extend new technology rather than the value of the improved practice *per se*. In general, agricultural scientists methodically pursue a line of study focused on some component of a cropping system with the firm conviction that their efforts represent the farmer's need. On-farm research or demonstrations are then designed by the scientists to show farmers the benefits of new technology. This scheme has been successful with the more aggressive, large land holders but for the most part has not convinced the small holders to make changes.

Extending Traditional Practices. The farmer, whether large or small, on hill land or low land, looks at his farming systems as a whole, one in which components are not always clearly separated. We as agricultural researchers tend to look at components and expect the farmer to be able to fit the pieces together as a unit. The small farmer and his family need an assured food supply, material for construction and fuel, clothing, tools and power for tillage. He also has a desire for some cash income, education for the children, and family social recognition within his physical and economic environment. Two factors may be important in our search to influence and hopefully improve his livelihood: (1) we do not know enough about his situation in its entirety and (2) we do not know whether present technology will or will not apply to his situation.

Perhaps our experimental approach should be modified to include the small farmer right from the beginning, not bypassing him. This implies the establishment of a base line from which he operates within his system of cropping, coming to recognize and appreciate his aims, desires, problems, and aspirations prior to designing on-farm research. During this time his inputs could be included in planning and execution of local research, collection and interpretation of results and implementation of findings. It is likely that one of the most significant findings coming out of the Puebla Project, a pilot study of how to increase maize yields among small subsistence farmers in rainfed areas of Central Mexico, could be summed up as "the goal should be something the people in the area feel is really worthwhile" (Jimenez and Laird, 1974). That "the small farmer should be involved in the decision-making process and should also be persuaded to make a resource commitment to the project" was a primary finding in an examination of 36 rural development projects operating in African and Latin American countries (USAID Report, 1975).

The suggested model of farmer involvement does not exclude the more strategic research conducted by trained scientists in national, regional and international institutions. It would, in fact, be a collaborative and interdisciplinary approach with a flow of ideas and information in both directions. Those who work directly with farmers, however, would need to possess a special sensitivity to their needs and to serve as a liaison between them and research workers. Thus, training of technicians is necessary for implementation of farmer-oriented research and its transfer to the small holder.

A similar operational approach has been taken by the Institute of Agricultural Science and Technology (ICTA) in Guatemala (Waugh, 1975), by the Agronomic Center of Tropical Investigation and Training (CATIE) and USAID Regional Office of Central America and Panama (ROCAP) in Central America (personal communication with Damon Boynton), and by the International Rice Research Institute (IRRI) in the Philippines (Harwood, 1974). It would appear, however, that none of these operations include an active participation of farmer groups as envisioned in the present proposal.

COMPONENTS OF CROPPING SYSTEMS

Components of technology such as varietal development, crop and pest management practices, soil conservation and water management and economic analyses, are vital in the assembly of alternatives within cropping systems. They are best studied, of course, at organized research stations or on pilot farms. Testing of such components, however, should be done within a management framework under which the practice is to be used. Many developing countries cannot, however, afford expansive research programs to cover the array of major and minor crop constituents of diverse cropping patterns. In some instances much can be accomplished with little investment.

An example of finger millet improvement in Nepal serves as an illustration (Rockefeller Foundation, 1976). Growing this crop for many years in isolated valleys and hill lands had led to considerable genetic variation. After two years of collecting and testing local types, with a minimum expenditure, yield increases of about 50% were obtained by selecting superior strains without additional technological inputs. Taking advantage of this initial diversity and maintaining a broad genetic base could be of tremendous benefit to small holders. Adding breeding

efforts in the search for certain desirable characteristics might provide another 15 to 20% advantage over a 5- to 10-year period.

RECYCLING NUTRIENTS

Animals make a significant contribution to hill land farming systems. They are usually omitted from studies of cropping systems, but are an essential component in the recycling of nutrients. This factor is of much greater importance to the subsistence farmer than to the commercial farmer. Bartholomew (1972) pointed out that the relatively low maize yields of 600 to 1 200 kg/ha remove about 15 kg of nitrogen in the grain. If we take into account the amount of nitrogen supplied by rainwater and nonsymbiotic fixation, such modest yields could be sustained over a long period of time with low inputs of fertilizer or through the use of ample compost. Animal management thus plays a major role in the intensification of farming systems in the hills. Attention to feed supplies both in terms of quantity and quality contributes to the well-being of animals and to their efficiency of nutrient recycling. Reserving land for production of forage crops is not always feasible, but including a legume in the cropping pattern provides a means of improving nutrient and feed supply.

Another source of feed supply on many hill farms is that of fodder shrubs and trees. A single farmer frequently recognizes 25 to 30 such plants, conserves them on his homestead, uses them extensively when they are found on communal holdings, but makes no effort to protect those off his farm site. Attention to fodder trees and shrubs could provide a three-pronged thrust in farming system improvement since a number of species supply herbage for livestock, fuel for burning and offer protection against soil erosion. *Leucaena leucocephala* is such a species. Once plants are established, leaves and twigs of this perennial legume can be repeatedly cut as high protein animal feed. When allowed to grow upright, plants produce a main trunk having a diameter of 10 cm or more within a year. If cut as firewood, then new tillers develop near ground level and sustain growth over many years with repeated cutting. Plants provide excellent ground cover and produce an extensive root system which, when properly inoculated with bacteria, fixes more nitrogen than any other tropical herbage legume (Hill, 1971). This species is restricted to regions free of heavy frost, but many other species and genera abound at different elevations and flourish under various environmental conditions. None has been fully exploited.

Of more immediate significance is the improvement of grazing lands. First, a scheme of grazing management must be imposed to avoid overstocking and overgrazing. Then more productive species should be introduced. Including a legume improves animal nutrition and soil nitrogen content. Use of phosphate enhances legume establishment, growth and persistence. If grazing lands are to be cultivated for crops, then a plan of land management such as strip cropping and field rotation should be employed. Such practices may demand government intervention, but they must have the sanction of village leaders as well as that of the people.

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DISCUSSION

S. B. Nepali (Nepal). Dr. Crowder has given the problems and even the answers, but I have not seen the package of programs that the hill farmers could pick up for implementing on hill agriculture sites where subsistence agriculture does exist. In this respect I would like to ask Dr. Crowder to refer to these Nepal conditions and also to take into consideration the North African mountains and the Andes. Taking all of these regions as a whole, I think it would be better to have one experiment station to study hill agriculture somewhere.

Crowder. We do have technology. We have technology and packages of technology, but usually they are aimed at single crops. If you go into the hill lands you seldom see single crops growing. You usually see some form of multiple cropping in the way of intercropping or mixed cropping. It's only recently that even the international institutes have begun any work with such schemes of farming. There are some programs at the Rice Research Institute, but they are aimed at rice and usually in the low lands. At the International Institute in Africa there is some research on mixed cropping. Interestingly enough, in Central America there is a collaborative program between CATIE, the Central American Institute at Turrialba, Costa Rica and ROCAP (USAID support) in which mixed cropping is an objective. In Guatemala, the Rockefeller Foundation has initiated some work on mixed cropping in cooperation with the government. What I'm saying is that we don't have that technological package for hill land agriculture at the moment. There are people who

will argue that present-day technology can be applied to small farmers. I'm not sure, I don't think we really know. I think your suggestion that an international institute be established to do applied research on hill land agriculture is good. Maybe we need national institutes to work on hill land agriculture, because people at international institutes should concentrate on regional problems, but isn't hill land agriculture international? The plight of small farmers in hill lands is truly international. There are a lot of correlations between Nepal and the Andean region. I don't think we've put together technological packages for global situations. I would welcome comments on this point.

H. F. Massey (Kentucky, USA). One of your slides dealt with the need for involving the farmer in the research-extension type program. I agree wholeheartedly with this. Do you have any thoughts on how such a program might be instituted in Nepal or any other country? What would be the cost, how would you arrange it, how expensive would it be to provide this type of integration, what would be the relationship between the government worker and the farmer or the farmer representative?

Crowder. There has been some work along this line at the International Rice Research Institute. It has been well documented by Dr. Richard Harwood, who worked at the Institute for several years. Researchers visited farms and talked with the farmers to learn what their problems are and how their systems of farming might be modified. The Institute team, however, imposed many of their own ideas in the on-farm research. As I indicated, similar work is being done in Central America.

For about a year at Cornell we were concerned about the lower 40% of the small farmers—a group largely bypassed or only marginally touched by modern research. We talked, argued, thought, but we didn't come up with anything until one day when a small group suggested that we needed to know where the farmer is before we could establish an operational base line. Our intent would be to involve a group of aspiring graduate students from the United States and from the country to be involved. They would collect information at the farmer level. They would go to a community and live there so as to become acquainted with and accepted by the people. It should take them about six months to acquire knowledge about the conditions of the farmer, find out where he is and what it is he wants to do. Some have asked, "Does this small farmer want changes?" Of course he does. He just doesn't want the kind of changes we're going to take out there—that's been the problem. How many times have you and I taken out demonstration trials, put them onto a farm, and paid the farmer for the use of his land. When we depart, what do we leave behind? A few pesos in his pocket! He usually does not adopt our trial practices. But we can obtain information and establish an operational farmer base line and then use farmer input for the planning of on-farm research. This goes one step further than that used at the International Rice Research Institute or in Guatemala, i.e., development of a farmer-oriented operational base line prior to planning and executing research. Perhaps 25 or 30 thousand dollars would suffice for the initial input for obtaining information needed to establish the operational baseline. This is sufficient funding to follow through, and we would only study one small community. Such a model would also involve researchers at national and international institutes. We trained people to acquire this information. We don't have them as yet.

Dick Tinsley (Philippines). I continued some of the research Dr. Harwood started and have been actively conducting research trials rather than demonstrational trials on approximately 200 or 250 farmers' fields. There is a technique that can be used and developed. It gets to be a fairly sensitive and difficult technique in any given area. I think we end up with something like a field staff of about twenty people, so that the interaction between the researchers and the farmer becomes quite sensitive. Frequently we use a fairly large fraction of his land and you can't concentrate any more of his effort than the fractional portion of his land that you're using merits, and this becomes a very difficult and sensitive problem to interpret. I think, however, we have had some degree of success. Certainly the normal experimental research techniques cannot be used. Variation may be extremely high. We have been able to note a fairly large degree of adaptation and modification within the farmer system for our efforts. We have also gained high appreciation for the ability of the farmer to be very accurately in tune with his resources. Whenever we have made any type of a change, we must identify a constraint to change because that farmer knows his resources and exactly what he is doing.

Gene C. Wilken (Colorado, USA). I agree with your statement that we don't have a technological package for the small farmer; I disagree that there is no technology. I think we sometimes feel that technology is synonymous with the Western World and I would argue that the small farmer himself has an elaborate technology; that these many farming systems mentioned represent an enormous collection of techniques for managing small plots and hillside farms. I would argue that this is a technology we should not ignore. This itself merits enormous investigation to find out if farmers have already solved some of the problems that we're only now becoming acquainted with. I see a trend in this direction—we

have suddenly discovered multiple cropping as a research objective, a technique the small farmer has been using for thousands of years. I wonder how many other useful techniques the small farmer has perfected?

Crowder. If I have inferred that there is no technology, I hasten to make retraction. I appreciate your comments and agree that there is a wealth of small farmer information which has been accumulated over centuries. This is what we're aiming at in establishing an operational line based on his information. We would have a team of people out in the field backed up by a group at a national or international institute or both so that we could get a flow of information two ways, i.e., information from the small farmer being fed into basic and strategic research at the institute and some technological approaches from the institute which could be immediately applied on the farm. We may not be sure they are applicable, but by working together I think we could perhaps come up with a different type of on-farm research.

I'd like to go back to Mr. Nepali's statement about an international institute for hill land agriculture. I agree that we do need broadscaled internationalized research on hill land farming. A number of international institutes exist, so instead of establishing another one, perhaps we could develop satellite research programs within the framework of national institutes. These might be jointly staffed by an international institute and by the national institute, using people who know the work within their country.

Don Plucknett (Hawaii, USA). I was told by a man in Nepal who knows the agricultural situation there that the farmers of Nepal are good, but the state of agriculture is poor. Perhaps outside technology or ideas could be used to improve the situation. If you've got a group of farmers who are very good in a very limited resource situation, who are managing those resources in a pretty good way given all the problems they have, then what is possible? Can we improve the state of agriculture in a country by helping farmers in their own system to take technology they feel will fit in their system that will give them some improvements?

There are farming systems that we should be studying: the farmers of Egypt, for example, who have managed for so many years to obtain high yields and have been little influenced by outside technology. If we really inventoried what they know, what a storehouse of information we could have. The farmers of Nepal, the farmers of China—all are very important sources of information, and then, Crowder mentioned the question of strategic research, we can focus research on the real problems of the farmer, not just researchable topics, but their problems. Hill lands are one major problem area where we've got to do a better job. Farming systems research is one of the ways of doing this, but it has to be farming systems research that starts with the farmer, not the experiment station.

Susan Almy (New York, USA). I want to talk about the Guatemalan program because it relates very much to how little can be spent to do a lot in this general area of hill land agriculture. The program of ROCAP and CATIE that was discussed actually started in El Salvadore with a very small group of people about four or five years ago and then was moved into Guatemala. They are working within the Ministry of Agriculture, with the usual agricultural research stations as backup. In Guatemala, they are actually working in three different kinds of hill land farming systems. There are only two or three people at each site working full time with two or three professionals plus four or five farmers—the economist, the anthropologist and the agronomist get together and plot strategies after a land use survey. All together there may be eight people working on a given project, but they are achieving some rather remarkable things at this point and the farmers that are involved are really bringing their own technology into it. While visiting recently we went to look at a complex multiple cropping experiment. The farmers had been folding a leaf over cabbage when it reached a certain height, then placing a stone on it. This is something they have been doing on their own plots with a slightly different kind of vegetable, so the agronomist just left it there. He figured that maybe they knew what they were doing, and it would be worthwhile to find out. You can determine such things at an extremely low cost. You may not obtain the kind of results that can be published, but the results might lead to improvements in farming systems in a developing country.

Jim Duke (Maryland, USA). I think perhaps it was Tom Odam, in his book *Environment, Society, and Power*, or some such title, who wrote that before exporting technology to third world farmers, we should import a little before we re-export what they know. There's a lot we can learn from them before we export our own technologies.

I am very close to Howard Highland in the Plant Introduction Office in Beltsville and I know that once something has been identified as having great promise for the tropics, we'll get a flood of inquiries for the germplasm. The speaker identified *Leucaena leucocephala* as one of the most promising legumes for the tropics. Now I don't know how far down the frost line is in Nepal or how high up the species will grow, but I would point out that it does not thrive where the annual temperature is lower than 16° C. *Leucaena* is very promising for the tropics, but not elsewhere.

Maurice Heath (Indiana, USA). Five of our great universities and experiment stations lie in the central part of the corn belt on rich, black soils. In this area, we've seen hill lands that have been committed to forestry for forty years that are now being cleared and put into rather profitable farming enterprises. I know there are some people who are very concerned about the small farms becoming covered with trees. To some this is good, but others say there must be a way of using such land in a more profitable agriculture practice. My question is, how do you move a great land-grant university like Cornell and its experiment station into the southern tier of New York to study the different intensification of agriculture for that area where farms have been disappearing? At one time there were good dairy farms on those hills. How do we get into the hill lands with manpower, money and facilities to live with these farmers that are trying to make a living and contribute to the economy?

Crowder. This touches a vital point, and one that our committee at Cornell wrestled—we called it the Back Forty Committee, since our interest was with the lower 40% of the farmers of the world. In some places it's 90%, isn't it? In the southern tier of New York it's probably 50 to 80%. This is a problem and we recognize it in New York. Quite frankly we don't know how to get into those hills. We have been accused of putting people out of farming for many years, and perhaps we have. I think we rationalized in earlier days that they should have been helped out of farming and into something more productive for them individually. Now an approach is being taken which might serve as a model. In Chenago County, New York, which is in the southern tier, an experienced woman is working directly with the county agricultural office, and her specific job is to go into the hills, become acquainted with the people, find out what they're doing and why. Hopefully this will provide information that the Extension Service can use.

Agriculture economists at Cornell say there exists a $2,000 capitalization per dairy cow—that's $50,000 for 25 cows, which is quite a small dairy farm. In this entire region 25 farmers had 25 cows or less and they were all over 55 years old. They were obviously staying on the land until retirement, after which it would be sold for old-age support. I don't think you build an extension program on that sort of base. Then the dairy herd was increased to about 35 cows, and at that point the numbers of farmers increased to about 50, with some 10 or 12 people who were under 45 years of age in the sample group. Now, it's a question whether these are subsistence farmers who are left or people who have moved out of the city, are still working there, and just happen to be living in the country. The clientele in Chenago County is thus different from the subsistence farmer in developing countries such as Nepal. This does not excuse us from addressing the problems at home first. We might say that *Hard Tomatoes, Hard Times*, the critical report on land-grant colleges, is not that far away. What are we doing in our land-grant institutions to reach the small farmers within our own states? I think it's a very good point. The cost of the program compared to the rest of our extension programs is essentially zero. I think we're putting about 25 or 30 thousand dollars of state money into the Chenago program each year.

In flying from New York to Ithaca, one sees all kinds of small blocks of land and can ask, "If I'm concerned about small farmers in other parts of the world, what can be done for the people down there?"

Robert Keefer (West Virginia, USA). New York and West Virginia have the same problem with the marginal, small farmer. We have research programs and some information may apply to these farmers, but how can we justify directing a certain amount of research toward them? What method do we have of doing this? Maybe I should say, what proportion of our research should be directed toward these small farmers?

E. B. Oyer (New York, USA). Does someone have an answer for that? I doubt very much if they do. I would say that research aimed at small hill land farmers can be justified. We have been able to justify quite an extensive international program in New York. After all, it is a local program and the economics of agriculture will show that these people have been bypassed. There can be justification established, but it has not been developed.

Herb Massey (Kentucky, USA). Suppose I'm minister of agriculture in some country and I'm sold on this approach: I want to put something like this into effect. Let's concede that maybe I have some resources that I can use or divert to the project. How do you go about doing it? How do you go about setting up an organization, a scheme or bureaucracy or whatever it takes that can operate in this way? One thing that we've had in the U.S.A. is a close system of working with the farmers. We get direction from them to some extent; many of our researchers work with them; and our extension people work with them. The farmers to some extent serve the medium that brings together the agronomist, the plant pathologist, the animal scientist and so on. Furthermore, they integrate efforts of these specialists. But in a society where the farmer does not make demands of the specialist, and does not feel that the government is responsive, there is a lack of such input. Now what kind of system could be established that would somehow use this input from the farmer? This is really the question I was trying to ask.

Milton Barnett (New York, USA). I wonder if we could apply this question to the project of the University of Kentucky with which Dr. Massey was associated and ask what results were obtained?

Massey. Some attempts were made to bring farmers in to field days, and to put research on farmers' fields. But I don't feel that this project would be judged successful in terms of the sort of thing that we're talking about today. This was really not a part of the original project scheme. What I'm really trying to get at is how could a government set up an organization that would have this type of approach built into the program.

Oyer. I don't want to put anyone on the spot, but I think we have some resource persons in the room who can bet at an answer to this question. I am convinced that leaders within a country must have a political will to implement such a program. In the U.S.A. we have the political will to do so. We have been able, it seems to me, to say to the large commercial farmer, "OK, we've served you pretty well but we've bypassed a group of people that we think we need to go back and help."

The government of Taiwan has a Joint Commission for Rural Reconstruction (JCRR) that has addressed the problem of working with people in mountains and has some projects developed for such regions. Would one of the representatives from Taiwan be willing to speak about the approach taken by the JCRR?

Hsiao-Tsai Wang (Republic of China). The Commission was given the idea of the project, cooperating with the governmental organization. The government gives them money and technicians every year. We can improve hill land farmers' conditions with technicians.

Oyer. So you've done it with technicians, but you also, I think, have the East-West Highway, which was a part of this, and the development of fruit lands in the upper part of Taiwan was again a part of this. You've done this with technicians but also with infrastructure. Would you say a little about credit? What credit has your government given to the farmers in these areas to help them develop, to use technology that you introduced?

Wang. Usually JCRR gives money for cooperative research from which data is obtained and extended to the farmer to show him how to use these experimental results.

Oyer. Taiwan, as you must know, has a very excellent farm advisory system and farmers' associations. Furthermore, special schools are held for hill land people.

Wang. Yes, we have a bureau, the Agricultural Resources Bureau, with technicians who are able to do something for the hill land farmers.

Oyer. I can testify that hill lands do exist in Taiwan. When visiting there, we drove as far as possible, then walked 3 ½ hours and still weren't at the top most village.

Charles Bailey (New York, USA). I would like to speak to the question of political will. Dr. Crowder has talked about farming systems and we've been concerned about the community and the farmers in that community, but, as I think we're all aware, these ecosystems exist in river basin The threats to the farming systems in the plains below are something that's been much talked about. In the hills of India there are really two aspects of political will—one relating to defense needs. Someone has remarked that probably the greatest factor contributing to the development of hilly areas in India is the People Liberation Army in Tibet, and that a lot of roads and public works have gone in since 1960-62 as a result. But they have been built without much reference to the people who live in the hills. A lot of the expenditure that has gone into the hills has come back again in the form of PWE contractors who come from the plains. A lot of the impact in road building, of course, exacerbated the condition of erosion. So that's one aspect of political will—motivation to put money into the hills, but again with programs that are not oriented to the people who live there. The other aspect has to do with river basin protection in the hills of Uttar Pradesh, India. In 1962 a program was instituted to protect the watershed above a dam that was built on the Ramganga. This was again directed to the farmers on the non-forested land. The program continued for ten years, with expenditures of 17 million rupees on such things as subsidized terrace reconstruction, fruit tree plantation and reforestation of community grazing land. There are no quantitative indicators which suggest that the investment had any payoff in terms of the primary interest, which is reduction of siltation at the dam site. Even so, this points again to government being motivated to do something in the hill areas, but being motivated by considerations that are above, beyond, or outside the hill areas, and in so doing, putting in money and putting in programs that have had very little effect.

Oyer. Would you care to say something about the UNESCO Project 7, which is for hill lands and tundra areas? Meetings were held in Bolivia and, I think, in Nepal.

Bailey. This is part of the Man and Biosphere program and there are about 13 projects. It's an attempt to bring scientists together in research networks around various kinds of problem areas and particular problems. I think the first six projects deal with particular problem areas, islands, mountains, tundra ecosystems and so forth. The meeting in Nepal

brought together scientists from all the countries that share the Hindu Kush scheme (India, Pakistan, Afghanistan and Nepal). People from Iran and China were invited, but they did not attend. I think the major conclusion of the conference was that so long as these kinds of problems are discussed in conferences which are set up by national bases, then the problems of international politics will dominate the scientific talk. That's exactly what happened in this case. A lot of the problems that Dr. Crowder has touched on and some that I have mentioned having to do with soil erosion and land destruction were touched on. It was a very assertive summary performance, I'm sorry to say. One recommendation was the establishment of an international institute. Unfortunately UNESCO doesn't have money to do this kind of thing, and this is where the matter stands.

Nepali. About the UNESCO and Biosphere Conference which was held last year in Nepal. At that time it had been decided to select a site in Nepal to have an environmental study center, possibly an international environmental study center, which does not relate much to agricultural aspects. The last time they discussed it, the emphasis was not on the economic aspects that we need in the developing countries to aid the economy of the hill people while maintaining the environment. Environment and economy should go hand in hand. In this case, I don't know whether the Man and Biosphere program is just looking along this line or just along the economic line.

Tinsley. The IRRI program in farmers' fields actually started after Dr. Richard Bradfield left and Gordon Bonton and Dick Harwood began to apply some of Dr. Bradfield's ideas to farmer enterprises. The program in the Philippines is established as a cooperative organization with IRRI as the leader. Perhaps it should be noted that, in general, agricultural technical staff in developed countries grew up on farms, went to school and returned to work in agriculture. Frequently, agricultural technical people in developing countries come out of the cities and do not have the "back to the farm" attitude.

IRRI is developing the cropping systems network in a way to encourage other countries to become involved in research. This has been adopted by several other countries in the rice-growing areas. Essentially, we select a project area which we feel suits our needs or the needs of the country that we're working with and then try to station people there, a team of economists and agronomists and occasionally weed scientists and an entomologist. The economist looks at the system as it exists at the present time. The agronomist tries to work with the farmer and through the farmer to find out what else can be done, both with the physical environment and with the farmer's resources. We find that we can push the physical environment to about one whole crop intensity higher than the farmer is physically capable of doing. This becomes one of our major problems, namely, to identify why this gap exists. We work with a few technical people and some local people in villages where they were born and reared. The latter become the liaison between the project and the farmer and go out and monitor the different trials near a village. To conduct research at the village level, we estimate we would need about 25 thousand dollars a year per project location for three years, not counting the international staffing, but strictly the local level staffing.

Oyer. Thank you very much. I would just point out that this exemplifies the model that one international institute has used and would also point out that national programs have to fill in and carry on where this happens. I think we can't escape the fact that national programs have to be involved.

Charles Adamson (New South Wales, Australia). The question seems to resolve into two factors—one, we're looking at the well-off and developed countries and, two, we're looking at the not so poorly underdeveloped countries that are producing food for their own domestic market. It seems strange to me in the United States where there is a food surplus that there should be so much attention focused on these small farmers and there should be such a lot of money spent trying to get these people on a better footing. What is being done to actually, say, aggregate these farms through lending institutions to try to make them larger and economically profitable?

Oyer. I would say that, as far as the United States is concerned, the lands that have been abandoned have not been the most productive for one thing. In New York, what you say is happening. Investment firms buy large areas of land and amalgamate them. And now they're coming to Cornell, looking for young graduates to manage these farms. So, from that standpoint, something of this nature is happening. The other point, for those of us who have lived through it, is that part of our real urban problems in the United States comes from getting rid of small farms and movement of people from the farms to the cities. So I think that a lot of the unrest in the late 1960s really had roots in the loss of the small farmer. I hope we're trying to plan ahead so that we can avoid this in the future with what we have left.

48.
Crop Production Complexes in Hill Lands of the Philippines

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HILL LANDS IN THE PHILIPPINES

The Republic of the Philippines is an archipelago arising in the Western Pacific and consisting of some 7 100 islands and islets of which 730 are large enough to be inhabited and support production complexes. The republic is divided into three regions—two large islands, Luzon in the north and Mindanao in the south and the cluster of islands in the middle collectively referred to as the Visayas. The islands are comprised of a series of predominantly volcanic mountains with a generally north-south trend. These mountains originate near, or perhaps below sea level, and generally do not extend to a height where cool temperatures become a major determinant in the cropping potential. The exception would be the mountains around Baguio in northern Luzon where many of the temperate vegetables are grown, and parts of Mindanao, which include the highest mountain in the Philippines, Mount Apo, 2 953 meters.

Most of the islands are climatically influenced by the southwest monsoon which divides the year into well-defined wet and dry seasons, with the cropping season for annual crops determined by the wet season. In addition to the monsoon, the country is affected by several typhoons each year, the wind from which can limit the potential for perennial crops in some areas such as the east coast. The exception to both these climatic situations is Mindanao which has a uniform rainfall throughout the year without typhoons.

Spreading away from the foot of most of these mountains are large, relatively flat alluvial intermountain or coastal plains. Where soil, landscape and rainfall permit, these plains are utilized for paddy rice, the staple food of most Filipinos, and the predominant agricultural production complex of the country. As with many parts of Asia, the need for rice to many Filipinos is almost mystic to the extent of their being unsatisfied when rice is not a part of their daily diet. Because of this demand for rice, it is grown in most areas where it is physically possible to grow it, even when a large amount of energy has to be expended to make the level terraces needed for paddy rice. On the relatively level alluvial plains, where most of the rice is grown, the diked and leveled paddy fields are developed on most areas in which the original slope is approximately 8% or less. In the more rugged areas, paddy terracing can extend up drainage ways surrounded by upland crops or up steeply sloping mountain sides. The ultimate is the famous Banawe rice terraces. However, these areas are not part of the major paddy rice production complexes.

Since rice has this mystical quality that encourages paddy cultivation wherever physically practical, the hill lands of the Philippines can be defined in contrast to the predominant paddy rice production systems as the areas in which topography is sufficiently adverse to normally restrict the establishment of the diked, level terraces needed for paddy rice cultivation.

This general and somewhat negative definition of hill lands, while accurately conveying the Philippine outlook, probably includes many areas that would not be included in hill lands in many countries where rice is not the staple crop. The definition is intended to include most dry land production complexes, even those based on dry land rice. It also is intended to include those production complexes in which paddy rice is a secondary crop, grown in the drainageways of a primarily dry land cropping complex such as sugar, as well as areas where extreme efforts were made to terrace slopes well in excess of the 8% slopes that normally limit paddy establishment in the major paddy production complexes. Certainly the Banawe rice terraces are a hill land production complex.

The hill lands support a wide variety of crops. In any area a specific combination of these crops will dominate in a homogenous manner to become a production complex. The specific production complex developed in an area is the result of the interaction between the physical resources available and the prevailing social-economic resources. The physical resources, including climate, soils, landscape, etc., determine which crops can be produced. The social-economic resources encourage certain crops at the expense of others, and place constraints on fully utilizing the physical environment. These resources include the on-farm conditions of power, labor, farm size, and off-farm resources of credit, inputs, government policy, etc. and support struc-

tures including transportation, market and processing facilities. The interaction of the physical and social-economic resources allows for a wide variation in production complexes even between areas of essentially equal physical resources and in the final analysis generally allows each location to have a unique production complex.

In this context, the production complexes in the hills can be divided into those which are almost entirely subsistence-oriented versus those which are largely commercially oriented. The first division relates to those complexes which utilize little or no capital inputs and consume virtually everything produced. This includes many of the more isolated complexes frequently involved in shifting cultivation, but also the Banawe rice terraces. The second division includes the more stable production complexes that generally have access to some form of supporting infrastructure. These can be subdivided into two systems; one involving small land holding and one, large plantations. The latter are frequently owned by large international corporations or their Philippine subsidiaries.

SUBSISTENCE-ORIENTED COMPLEXES

Subsistence-oriented complexes are those in which few if any external inputs such as fertilizers, pesticides or even improved seeds are used, and from which little produce is marketed. Frequently these systems are located in highly isolated areas in which distances are measured in walking days. Thus even if inputs were available, often it would be impractical to transport them to the location needed, or transport the increased production to the market for sale. The capital frequently used is used for metal implements such as bolo knives, axes and hoes, or the raw material (automobile spring steel) from which the implements can be forged locally.

Although many of these systems are in isolated areas, the inhabitants do interact with other groups involved in more commercial systems as well as the government. Frequently, the hill people serve as a migrant work force for lowland areas or supply draft animals on a seasonal basis to their lowland compatriots (Wallace, 1970). Occasionally, the people even file land claims or pay token taxes to the government (Oracion, 1963; Wallace, 1970). The exception to this interaction would be the Tasaday tribe, which was only identified in 1971 as a stone age, gathering society in an isolated section of Mindanao (Nance, 1975). Several examples of these systems are presented below.

Shifting Cultivators

Probably the most common and widely written about of the subsistence complexes are the shifting cultivators. In the Philippines shifting cultivations can be found throughout most of the islands. The swiddens made by them can easily be recognized from the air as irregular patchwork of clearings and secondary regrowth in the forest reserves. The management of the swiddens is practically the same throughout the islands (Dozier, 1966; Oracion, 1963; Wallace, 1970), and not significantly different from the shifting cultivation found throughout much of the tropics. In general, the vegetation is cut or girdled early in the dry season, dried for a month or more, then burned just prior to the first rains. The fields are then planted to annual crops for two or three years. As the productivity decreases, the fields are used for biennial and perennial fruit crops such as papaya and banana before being abandoned to natural succession for several years. The decline in productivity is most often attributed to depletion of nutrients. Since there is frequently a rapid, succulent regrowth in the swiddens, all of which requires significant plant nutrients, the decreased productivity could partly be attributed to the build up of plant pathogens, or the invasion of hard to control weeds such as *Imperata cylindrica*, known locally as cogon grass.

During the initial period of cultivation, the swiddens are used for a low-yielding, intensive, multiple cropping system centered on dry rice. Dry rice is planted on virtually all the open area of the swidden, frequently randomly intercropped with corn. Vine crops such as several types of climbing beans, sweet potatoes and bitter gourds (*Mamordica charantia*) are planted around the large trees not cut and burned, but defoliated and left standing in the middle of the swidden. Finally, around the edges, egg plants, cassava and pineapple are planted to form a crude protective fence (Wallace, 1970). After the corn and rice are harvested the swidden is replanted to another combination of crops. These include more corn plus some of the more drought-tolerant legumes such as mungbeans, cowpeas and peanuts. In some parts of northern Luzon, tobacco is a major post-rice crop (Wallace, 1970). This is a cash crop, having sufficient value per kilo to justify hauling to market from the isolated areas.

Between the harvest of the first crop and the planting of the second there is normally a delay of one month or more (Wallace, 1970). This occurs repeatedly in many complexes; it comes during the middle of the rainy season and appears to represent a loss of one month prime growing season. One reason for the delay could be that priority is given to securing the rice crop, before planting the second crop. Securing the first crop includes harvesting, threshing and drying. This can require more than 400 man-hours per ha, or one man-month, if rice is harvested panicle by panicle and threshed by

rubbing with the feet. These techniques are common in some of these systems (Dozier, 1966; Wallace, 1970).

If there is a second and third year of cultivation, the ratio of corn, cassava and sweet potatoes to rice will increase. This is because these crops are more competitive with the invading weeds than is dry rice. All the annual crops are planted without any land preparation other than dibbling with a sharp pointed stick. This can be seen as a soil conservation technique, which is also used on severely eroded portions of more stable production complexes. Since the shifting cultivators do not anticipate long-range land tenure, they generally do not become involved in extensive soil conservation efforts, much to the dismay of the government.

The produce of the swidden frequently does not provide either a sufficient or balanced diet. In Mindanao there are areas in which shifting cultivators suffer from severe vitamin A deficiency or goiter (R. R. Harwood, personal communication). Vitamin A deficiency can be corrected by including other native fruits in the diet, whereas correcting goiter will require other means of introducing iodine into the system. Deficiencies in total production are frequently made up on the cash economy by selling bamboo or tobacco, renting draft animals and doing migrant work. The bamboo is frequently the prime source of capital, although the crop is gathered more from surrounding forest reserves than cultivated. The tobacco is cultivated specifically for cash purposes. Occasionally, surplus fruits are sold. These include bananas or plantains as well as some fruits badly needed for their vitamin A content. The migrant work includes transplanting and harvesting rice on lowland fields or cutting sugarcane during the dry season.

A typical swidden can be as large as 3–4 ha, the clearing and preparing of which is generally a joint community effort, although it will belong to one individual or family. The outside labor used is exchanged labor which carries an obligation for repayment in future clearing operations. Although the land is acquired gratis, used and abandoned to natural succession, there remains a lingering claim to the land by the original clearer (Dozier, 1966). Usually no one within a community will attempt to reclaim and work an area without the original clearer's permission. There are times when outsiders will occupy the land because they are unaware of these traditional claims. This is frequently a cause of conflict between shifting cultivators and more commercial-oriented settlers immigrating into the fringe areas, as infrastructure is developed. To protect themselves from this, some shifting cultivators file legal claims on their land with the government (Dozier, 1963).

The general view of the government toward the shifting cultivators is that they represent a destructive force on the country's valuable forest reserves. This is because of the cutting of good timber trees and also the accelerated erosion of the barren slopes. The government has made several attempts to curtail shifting cultivation. A major part of this effort has been to forcefully resettle the hill tribes in lowland areas, providing them with land and some resources to develop a stable production system. More recently efforts have been aimed to encourage the residents to adopt various stable tree culture production systems, involving plantation crops or forest crops (Oracion, 1963). Unfortunately, many of these plantation crops require extensive infrastructural support for processing the produce. In many of the isolated areas this support does not exist.

The prospect for shifting cultivation systems is most likely to develop more stable forms of commercially oriented production systems. In many areas the physical environment should support different plantation cropping systems based on coconuts, rubber, abaca (*Musa textiles*), cacao, coffee, etc. These systems frequently require a supporting infrastructure, which must be provided concurrently with crop development. Once the infrastructure has been developed, the shifting cultivation frequently has given way to more stable capital intensive systems.

There are areas where shifting cultivation exists directly adjacent to or even as a part of other more stable commercially oriented production complexes. Examples are seen in the small hills directly beside IRRI and within the University of the Philippines, Los Baños campus, which include the foremost agricultural experiment station in the Philippines. In these areas of persistent shifting cultivation, the shifting technology could easily be the most suitable for the resources available in the specific locality.

In the shifting cultivation areas it should be possible to develop a stable subsistence production complex that will provide an adequate amount of a balanced diet. Most likely such a system will have to get away from rice as the staple crop and concentrate on plantains (*Musa paradisiaca*) and other tree crops. This might involve reconstructing the natural rain forest with a mixture of nutritionally valuable plants.

Banawe Rice Terraces

In a portion of the Alimot River basin as it flows through the mountains of northern Luzon, the Ifugao (ethnic inhabitants of the area) have constructed rice terraces that extend from the river bottom nearly to the crest of the mountains. Those terraces begin as low as 200 m above sea level and rise continuously, one after another, to approximately 2 000 m (Van Breemen *et al.*, 1970). This forms what frequently

is referred to as Staircase to the Sky. Construction of these terraces represents a remarkable engineering feat that has gone on continuously for more than 3000 years using essentially simple hand tools, plus a superb understanding of hydraulics engineering and fluid transport. This has resulted in a unique indigenous production complex of which the country is justifiably proud.

The government is promoting the area as a tourist attraction. The government has built a road system to Banawe, over which commercial activities flow. Despite this support, the rice production in the terraces remains essentially subsistence. This indicates that a more productive rice technology for this area possibly does not exist. The terraces represent an area where cool temperature affects the growth of the rice. IRRI, presently, does not have any high-yielding cultivars adapted to cool temperature, although IRRI maintains varietal screening plots in an effort to obtain such a high-yielding cultivar.

There is irrigation water available year round. However, most of the terraces are used for a single rice crop occupying only half the year. Recently, some parts of the terraced areas have begun double cropping rice. Single crop rice is sown in October or November, transplanted in January or February and harvested in July, after which the terraces remain essentially fallow until the following January. Relating this to the rainfall pattern, the rice is actually grown through the dry season and harvested in the beginning of the wet season. At first review this would be reasonable since the incident radiation in the dry season is greater, and rice grown in the dry season is more productive. However, the critical period in which radiation is highly correlated with yield is the period of grain filling or the 45 days just prior to harvest (De Datta and Zarate, 1970). In the Banawe system these last 45 days occur during the early wet season when clouds reduce the available incident radiation.

During the remainder of the wet season the paddies remain flooded and fallow, though occasional Taro (*Colocasia esculenta*) is grown, and snail, clam and mudfish that live in the terraces are collected (Conklin, 1974). Those who produce a second crop of rice transplant it soon after harvest of the first crop and harvest it in December in time to get the fields ready for the main crop. Virtually all the work done in the terraces is manual labor without use of either draft animal or machine. Most terraces are just too small for draft animals or machines. The rice produced in terraces is either red rice, which has highly desirable flavor, or glutinous rice, which is frequently used for ceremonial wine (Van Breemen *et al.*, 1970).

The entire production complex includes more than just the terraced rice paddies. On some of the slopes that are too steep for terracing or have not yet been terraced, shifting cultivation, as described above, is practiced by some of the same families involved with terrace cultivation (Conklin, 1974). Also, some of the dikes are planted to various crops, and occasionally individual small paddies will be planted exclusively to upland crops.

Even with all these extra efforts, the production complex is not adequate and rice has to be purchased from outside sources. Capital for these purchases comes from income from either migrant labor on more productive lowland fields, or manufacture of souvenirs for the tourist trade being fostered in the area by the government.

Land tenure on terraces is highly structured with the ownership frequently traced back through generations to the relative who first built an individual terrace (Conklin, 1974).

COMMERCIALLY ORIENTED COMPLEXES

Production complexes with commercial orientation are those that utilize significant amounts of inputs and market significant portions of their production. These are actively involved in a market economy although they may produce some subsistence crops. They must be sufficiently close to roads for convenient transport of goods to market and inputs back to the farm. These systems essentially have a stable land tenure, either with ownership by the operator or rent/lease agreements. Current land reform efforts are effectively eliminating sharecrop tenancy and breaking up large absentee estates. These commercially oriented production complexes can be divided between small farms operated by individuals or families and large corporate plantations operated by a large force of salaried employees. Many of the latter are owned by international corporations or their Philippine subsidiaries. Included in this are Castle & Cook (Dole), Del Monte and Standard Fruits.

Small Farm Systems

The small farm systems usually involve less than 10 ha and frequently only 1.5 ha or less. They are generally operated by a single farmer and his family with outside labor only during peak operations, such as harvesting and threshing of rice. In general, the cropping systems on these farms are highly intensive and highly diversified. They will include a combination of both cash crops and subsistence crops, and frequently utilize such intensive techniques as intercropping and/or relay cropping of annual crops, as well as vertical canopy stacking of perennial crops. Despite the high intensity, most of these systems were developed directly within the local farm communities without major outside assistance from government or private agencies in the form of research or extension activities. In most areas the physical environment will support a large variety of potential

crops. The actual system finally selected will frequently be a subset of those crops physically feasible for which infrastructure support is available for marketing and processing of products raised. Some examples of these small intensive farm systems are discussed below.

Cale Batangas (Diversified Upland Rice)

This is a highly productive village in which the IRRI cropping systems program has been actively involved for the past three years. The village is part of the municipality of Tanauan, Batangas Province, which is approximately 70 km south of Manila. Trucks biweekly use an unpaved road through the village to pick up produce for sale in Manila or Tanauan markets. The village consists of some 400 families with an average of six members per family. The average size operation is 0.9 ha, from which many families have been able to send their children to college.

The productivity of the village depends on a highly favorable soil. The soil has been tentatively classified as Andepic Argiudols or Andepic Hapludol, and ranked in the upper one percentile of the world's most desirable soils (Frank Moorman, personal communication). The village is on the back slope of one of the world's largest volcanic cauldrons, in which a small active volcano remains. The soil is thus derived from volcanic ejects, and appears to contain a large amount of amorphous material that makes for strong stable aggregation and organic matter accumulation. This makes the soil well-drained, and easily tilled even with heavy monsoon rains. In addition, nearby Taal Volcano replenishes the fertility through periodic eruption, such as the present one, so that crop responses to P and K trials are not obtained despite heavy cropping. This also makes extrapolation of this production complex to other areas inappropriate.

The production complex centers around the cultivation of upland rice, which serves as a staple subsistence crop. Upland rice is generally a difficult crop to grow because of weeds. The Cale farmers use a deep vertically rooted rice variety (Dagge) and take maximum advantage of the high tillage capability of their soil. They have developed cultural practices that allow a nearly weed-free rice crop without the use of herbicides. Cultural practices combine mechanical cultivation and a high seeding rate. The rice is broadcast yet forced into rows, then cultivated both along the rows and diagonally across the rows. These operations are repeated about three times during the first month after planting, after which the rice develops a full canopy that shades out further weed growth. This technique can not be successfully utilized on less well-aggregated soils, restricting good upland rice to areas that have soils with the structural stability of Oxisols or Andepts.

The rice is essentially a subsistence home-consumed crop. It is grown during the first half of the rainy season, requiring approximately 120 days to reach maturity and occupies most of the cultivatable land during this period. Frequently, it is intercropped with corn either in rows about 2.5 m apart or randomly. In the latter case, the corn is used as early fodder for the draft animals. The corn-rice intercropping has been shown to be one of the most productive intercrop combinations at IRRI (Harwood, 1976).

After the rice is harvested there is generally a one-month delay before additional annual crops are planted. These second crops include grain corn, green corn, bitter gourd, garlic, cowpeas and mungbeans. Sponge gourd *(Lupsa culindrica)* is often relayed (successive planting in a standing crop prior to maturity of the latter) into the rice. It is planted after the rice has headed. The rice straw is then laid down as a mulch. Garlic is also frequently mulched with rice straw cut and stacked for this purpose. The IRRI effort in the area has shown that sorghum with a single ratoon (successive harvests from original planting) is well suited for growing after rice, but farmers have been reluctant to grow it for lack of market and difficulty in threshing without mechanical power threshers. However, farmers did grow it in a special project in which IRRI and the Bureau of Plant Industry developed a suitable market and provided threshers.

Land not used for rice is also intensively cultivated to several cash crops, the most productive of which are the trellises which are cultivated almost year round. The first crop is sponge gourd. This is planted during the dry season and hand watered while it climbs the poles onto the trellis. The fruit is ready to harvest by July and continues with biweekly harvest until October. This is a high value crop and great care is taken to protect the fruits from fruit flies. The protection consists of placing plastic liners around each fruit as it emerges. As the sponge gourd slowly declines, wingbeans (*Psophocarpus tetragonolobus*) ascend the poles to replace the sponge gourd. These are sold as a green vegetable until the dry season begins in January. Even the area under the trellis will be planted to a variety of shade-tolerant crops including taro, ginger, cassava, eggplant and occasionally rice.

Another high value, boom or bust, cash crop sequence is eggplant, relayed with hyacinth bean *(Dolichos lablab)*. The eggplant is grown in the beginning of the growing season. When an early typhoon devastates the crop in central Luzon the farm price of eggplant can reach as high as US $1.00 per kg. This happened this year only to have the crop destroyed in later stages by volcanic ash. Frequently, Cale farmers plant eggplants in highly protected fields so typhoons will pass over without dam-

age to them. When typhoons do not occur the price can plunge to marginal levels. As the eggplant deteriorates, the fields are planted with hyacinth beans. This can be grown as a green vegetable almost throughout the dry season. The plant is a climbing vine which grows up and completely engulfs the eggplants. This provides good ground cover to reduce weed growth.

An additional early cash crop is bush sitao, a Philippine cross between cowpeas and pole beans. It has a bushy plant but pole bean fruit. This crop is planted early in the rainy season and marketed as a green bean. It is the first crop to be harvested and sold. Thus it serves as an early source of capital needed to purchase the inputs for the other crops. Bush sitao will be followed by either corn, bottle gourd *(Lagendria siceraria)* or pepper. The latter is aimed at a Christmas-New Year market when peppers are in high demand.

The last portion of the Cale production complex is coconut. This is a low-management crop frequently referred to as a lazy man's crop, but might be more accurately classified as a retiree's crop. The system is that as a couple get older and their obligations decline, they will plant coconuts to provide the necessary income during their retirement from heavy cultivation. These groves are intensively intercropped with annual crops prior to becoming productive, and may continue to be subcropped while in production. However, yields of substory crops decline as the coconut canopy fills in.

Tagaytay, Cavite (Canopy Stacked Intercropping)

Slightly to the west of Cale along the same volcanic cauldron is the Tagaytay ridge. This area has somewhat more sloping topography than Cale, with a slightly wetter climate because the ridge more directly intercepts the monsoon circulation. It appears to have a highly stable soil similar to that found in Cale. Access to the area is by mostly paved roads, allowing shipping of produce to Manila where coffee and pineapple processing facilities are available. Farmers use an intensive multiple canopy intercropping system that is not only agronomically sound but aesthetically attractive as well. The system is essentially a reconstruction of what would be a natural triple canopy rain forest, using economically valuable plants. Up to four canopies can be easily distinguished in Cavite, although three canopies are more common. The upper canopy is almost always coconuts. These are spaced wider than for coconut monoculture. The second canopy frequently is either papaya or bananas, and the lower canopy can have cash crops of coffee, pineapple or annual subsistence crops such as rice, cassava, taro, beans and sweet potatoes. The open lands of Cavite are used for a variety of both subsistence and cash annual crops. These include upland rice, corn, intercropping of rice and corn, cassava, taro and pineapple with some intercropping of the latter two. In addition, some areas are devoted to African daisies. They are in high demand on November 1, All Saint's Day, when most Filipinos pay homage to their deceased ancestors.

Agusan del Sur Resettlement Area (Another Canopy Stack)

This is an area of rugged low-elevation hills, arising abruptly from a river plain. The area has highly eroded, acidic soils, frequently with none or very little topsoil. The plains are rapidly being developed into paddy rice areas. Hill portions are involved in mixed tree crops that are beginning to evolve into a more orderly canopy stacking intercrop of tree crops. In this case, the upper canopy is rubber, the second canopy abaca or coffee, and the bottom is used for subsistence crops including cassava, ginger and sweet potatoes. This is ecologically a highly desirable system for the area, since the permanent tree crops provide a continuously full canopy that covers the land and protects it from additional erosion.

The abaca has been an established crop for some time and has a market structure. The abaca is used for Manila hemp, a valuable cordage that is almost an exclusively Philippine product. The market structure for rubber, which is just reaching tapping age, has not developed as yet, although the Mindanao Agricultural Resettlement Agency (MARA) is planning a processing plant for the area. MARA is a church-related private development organization that encouraged the planting of rubber and has provided technical support for establishing it with the idea of building the processing plant. Firestone has a plant near Davao approximately 200 km south of the area. Those who have begun to tap the rubber are coagulating it with acetic acid in coconut shells. The resulting product brings a discouragingly low price—only about US$0.15 per kilo. The use of two or more cash crops such as rubber, abaca and/or coffee can stabilize income on small farms. The farmer can absorb some fluctuation in price or yield in one or two of the commodities he is involved with.

Open portions of the hill area are used for quasi-shifting cultivation form of rice production. The rice is dibbled with a stick in unplowed fields, even though the rice paddies adjacent to the field are prepared by draft animal and steel plows. In this case the dibbling appears to be more a method of soil erosion control than due to lack of plowing resources.

Pangantucan Resettlement Area, Bukidnon (Corn/Upland Rice)

This is an area comprised largely of well-weathered red soils that have plenty of free Fe_2O_3, but fall short of being Oxisols (Frank Moorman, personal communication). The soils are well aggregated with tillage characteristics similar to those of Cale and Cavite discussed previously. They are more acidic and less fertile than Cale or Cavite soils with a possibility for having strong P adsorption.

The area contains some irrigated plains, which are in paddy rice. However, the hill areas are mostly in corn and upland rice, frequently intercropped. The cultural techniques for rice are similar to those of Cale, with no dibbling as in the Agusan area. These two grain crops receive government support pricing when marketed through the National Grains Authority. Coffee is beginning to be grown in the higher portion of the area. Initial plantings are heavily intercropped with subsistence crops, but this eventually gives way to monoculture as the coffee matures and becomes productive. No shade is provided for the coffee.

Conspicuously absent from the cropping system are the normal legumes such as mungbeans and cowpea found in most of the country. This may be a result of molybdenum unavailability due to acidic soil condition. This would reduce the nodulation and nitrogen-fixing potential, so advantageous with legumes. Those few wild and cultivated legumes found by the writer in the area did not have root nodules.

The area would appear to have a higher production potential than presently demonstrated. Banana and sugar are grown under similar conditions. Del Monte maintains a large pineapple plantation not far away with similar soil and climatic conditions. However, sugar mills and pineapple processing facilities are not presently available.

Capiz Resettlement Area (Sugar Paddy Rice)

The Capiz area is a rolling hill section of the island of Panay in the Visayas, in which sugarcane is combined with paddy rice. The paddy rice appeared originally in the drainage ways but is expanding across the valley floors as new paddies are constructed. The hill areas near the roads are almost exclusively in sugarcane which is marketed through the Philippine Sugar Central in a neighboring town. However, sugarcane is a large bulky crop requiring an extensive transport system from field to mill. Thus it can only be grown on a relatively narrow fringe beside main roads and feeder roads coming into them. As one goes away from this supporting infrastructure road system he will note that the cropping rapidly changes to strict subsistence crops of corn, upland rice, sweet potato, etc. The land and climate can most likely support a large range of other crops, but as long as sugarcane has the marketing structure, regardless of how unstable the market, other crops appear to have little chance for development.

San Joaquin, Iloilo (Diversified Terrace-Upland)

At the other end of Panay Island from Capiz, near the border of Iloilo and Antique Provinces, is a highly diversified production complex. An example is the farm of Cresencio Servano (Rose and Cresencio Servano, personal communication). The farm has been in the family for several generations, although Cresencio's father (Apolonio Servano) is largely responsible for developing the farm to its present size of approximately 18 ha. This is a little larger than most small farms, and some of the land is rented by relatives. Apolonio was able to assist all his eight children to obtain college education even though he could not read or write.

The farm is divided into four cropping systems. The first is terraced paddy rice. This includes several ha which have been terraced over a period of several generations to form level stable rice paddies. These are used for the principal crop of rice that is directly consumed by the family as a whole including those no longer living on the farm. The second is the upland crop and coconut area. This area has unlevel terraces that were formed by letting soils erode against a coconut hedgerow. These areas are used for annual crops under the coconuts, including corn, peanuts, cassava, sweet potatoes and occasionally dry rice. These crops are also generally consumed although the corn is frequently fed to pigs and chickens which are then sold. The third system is mixed fruit orchards, including a variety of tropical fruits, mostly for home consumption, although surpluses would be sold. These include coffee, cacao, guava, avocado, starapple *(Chrysophyllum caimito)* calamansi *(Citrus mitsi)* etc. The final cropping system is coconut and bamboo. These are essentially very low management crops, but are the biggest capital earner; the proceeds provide the inputs for other crops grown for consumption. The coconut is used for seedlings, copra, cider (locally called tuba) and vinegar. The bamboo is sold largely for construction of anything from houses to fish traps.

In the past, the Servanos raised sugarcane, but discontinued it when the mills in Antique closed as more modern mills were established in Iloilo. They recently obtained a loan to grow sorghum. They were able to successfully grow it, but had difficulty threshing and couldn't sell it. Finally, they were forced to feed it to their pigs and market the pork.

Baguio (Temperature Horticulture)

One of the largest and most important of the hill production complexes is the vegetable and cut flowers system just north of Baguio in northern Luzon. The elevation is sufficient to have the cool temperature needed to grow temperate vegetables. The area is within a day's drive of Manila, where most of the vegetables are marketed. The crops are grown on narrow terraces that cover entire mountainsides. The area is well known for its strawberries, potatoes, cabbage, beans, cauliflower, carrots etc. Also, they grow many cut flowers including roses and everlasting flowers. The latter are essentially dried marigolds strung together.

PLANTATION PRODUCTION COMPLEXES

The plantation production complexes are those in which large tracts of land are cropped to a single commodity under one management unit. Frequently, these areas are owned by such international giants as Castle & Cook, producers of Dole products, Del Monte and Standard Fruits Corporation or their Philippine Subsidiaries. Crops produced on these plantations are frequently exported and are a prime source of foreign exchange for the Philippines. Most of the plantations are under private control or highly autonomous government boards. They usually have their own research and extension operations, as well as processing and marketing facilities. These production complexes can be conveniently reviewed by commodity.

Coconut Copra. This is governed by the Philippine Coconut Authority which operates a series of research stations in the major coconut-growing areas. The largest area is in mountainous Quezon Province on the eastern edge of Luzon; other areas include various parts of Mindanao. In Quezon the coconut plantations extend over entire mountainsides. The coconuts are frequently collected and transported to the road by small horses with baskets mounted on their sides. Once at the road the coconuts are husked, opened and dried into copra from which oil is pressed. The husks are frequently made into charcoal or used to fuel dryers in drying the copra. The industry as a whole is Philippine-owned with sufficient output to make the Philippines the major exporter of coconut oil, 62% of the world's output in 1967 (Woodroof, 1970). Many of the coconut groves will be subcropped with shade tolerant perennial fruit crops such as bananas, coffee and lanzones *(Lansium domesticum)* in southern Luzon, or abaca in Mindanao. These intercroppings are accomplished without reducing the coconut stands as happened in the Cavite intercropping system.

Sugarcane. The sugarcane industry is regulated by the Philippine Sugar Institute (PHILSUGIN), a government cooperative serving large and small sugar producers. The actual growing of sugarcane is strictly in the private sector, including the research and development. The overseas marketing is done through the government-owned Philippine National Bank.

The Visayas are principal sugar-producing areas. Additional major areas are in Tarlac, central Luzon, with some operations just beginning in Mindanao. Sugarcane is essentially a one-year crop harvested during the dry season from October to April. Frequently, two ratoons are grown after the original crop is harvested. In general, sugarcane is not as productive as it could be, largely due to an inadequate delivery system in which cane-laden trucks frequently have to wait several days at the mill before unloading. During such periods the cane ferments and the sucrose content rapidly decreases, resulting in more molasses and less sugar per ton of cane.

Bananas. The major export banana plantations are in Mindanao. Mindanao is south of the typhoon area, thus the prospects of high winds destroying a heavy fruited crop are slight. Most of this production is under control of international companies which ship bananas directly from the plantations to Japan. These companies employ their own research personnel to develop and improve technology.

Pineapple. Like banana, pineapple plantations are located on Mindanao and are largely controlled by international companies. The largest is Del Monte, located on the flat remains of a dissected peneplain spread over several km. The landscape and soils are similar to those Del Monte uses in Hawaii. Again, as with bananas, the companies provide all their own support personnel for production, processing and marketing. Most pineapple is sold as canned fruit and juice.

Pasture/Beef Production. Although the Philippines have large areas that would make good pasture land, the pasture/beef industry remains small and of only minor importance. The consumption of beef ranks fourth as a source of animal protein, well behind fish and pork and close to poultry. Most of the pasture lands appear to be cow-calf operations as much to supply draft animals as beef. Heifers generally are fattened for beef, while bulls are used for draft. Such grazing complexes as there are, are concentrated in Tarlac and Nueva Ecija, provinces of central Luzon, plus parts of Mindanao and the islands of Palawan and Masbate. The pastures in Nueva Ecija frequently utilize the natural degraded grasslands resulting from excessive shifting cultivation and erosion until bare rocks are observed on the hilltops. In Mindanao, cattle frequently are grazed under coconuts. Generally, only natural grasses are grazed—improvements could increase the carrying capacity. The marketing structure

appears well developed with most animals from southern islands moving into Luzon through Batangas Province. Here they are fattened prior to being marketed in Manila. Despite the potential to produce beef within the country, beef is regularly imported from Australia.

Forest Reserves

The forest reserves are government lands managed by the Department of Natural Resources. They comprise approximately 40 million ha throughout the Republic with pines and hardwoods, including eight species of Philippine mahogany. The forest reserves serve as a major source of foreign exchange from the sale of logs, finished lumber and wood by-products. A large portion of these goes to Japan. Cutting of the reserves is largely by private contractors. After cutting, much of the area is reforested by natural succession, although controlled reforestation is practiced in some areas. The total forest reserves dwindle each year due to encroachment of shifting cultivators and poor management on the part of some contractors (Reynaldo de la Cruz, personal communication).

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49.
New Systems of Hill Farming in Scotland

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The pattern of hill farming today, as in any other major branch of agriculture, is the result of successive generations responding to economic realities within the physical constraints of soil and climate. In hill country the degree and rate of change in response to fluctuating economic conditions is very much more limited by the rigidity of the physical framework than in lowland agriculture. Nevertheless, changes are taking place slowly over time and a "new system" in livestock farming is not a destination but a staging post along the trail. Nor, unfortunately, is it always a case of ever forward progress as tracts of abandoned land around the world testify. Any new method of management is meaningful only when viewed against the background of the present system which, for the majority of Scottish hill farmers, is traditional.

THE PHYSICAL CONSTRAINTS AND THEIR ECONOMIC CONSEQUENCES

The combination of poor, shallow and often highly acidic soils at high altitudes and under a regime of relatively high rainfall has meant a vegetational cover of low nutritive value and, consequently, of a low stock-carrying capacity. This complex of plant communities on the hill is termed rough grazings and is akin to the American term, range. On Scottish hill farms more than 90% of the land is under rough grazings. Only the hardy breeds of hill sheep can come through the winter on the hill and in-lamb without hand feeding except in times of heavy snowfall. On farms with adequate natural shelter, beef cows are successfully outwintered on the hill, but the limiting factor, for both outwintered and

inwintered herds, is home-grown feed. In hill country the extremely scarce but valuable cropping or in-bye land is confined to the better soils along the valley floor and on the lower slopes where cultivation is possible. This topographical feature is a severe constraint on the balance of enterprises and on the stage of selling of lambs. Such a small proportion, nationally 2%, of improved land on which to grow winter food for cattle and/or folding crops for fattening lambs means that the main enterprises must be sheep and the bulk of the lamb crop must be sold in store condition. Although this environmentally enforced specialization has its benefits, mainly on the technical side, it has the accompanying economic disadvantages, serious in times of low profitability in sheep, of lack of diversity, severely restricted access to the guaranteed end-product market and a marked seasonality of production pattern leading to an irregular cash flow.

The contrast between hill and upland farming in Scotland is shown in Table 1. The upper part of the table illustrates the relative importance of these two distinct sectors in terms of land use. Hill farms, although relatively few in number, occupy over three-fifths of the Scottish grazings and are the main reservoir of sheep, whereas the upland sector is the heartland of the national beef herd. The lower part demonstrates the dominance of physical factors in the determination of the basic structure. The difference between the two types of farming is one of environmental degree.

The seasonal management is also governed to a large degree by environment. In the traditional system the ewes are set-stocked on the hill all the year round with the size of the flock being determined by the winter-carrying capacity. This leads to considerable under-grazing of the hill in summer with all the concomitant penalties that flow from such a grazing regime. For centuries flockmasters had no alternative for they knew from experience the dangers of exceeding the numbers of ewes that a hill could safely overwinter albeit at a tolerable minimum level of nutrition. The fluctuating volume of output from year to year due to seasonal factors is another well-known characteristic of hill farming. Seasonal effects are most clearly seen in the level of the lamb crop as conventionally measured by the lamb marking percentage in June. The results over 20 years from a largely identical sample of some 30 hill farms in the Highland region of the West College Province are given in Figure 1.

The decade of the sixties was poor with only the lamb crop of 1961 exceeding the 20-year mean of 75%. The improvement in the present decade is significant. Never before have the sample averages been over 80% for four consecutive years. (The provisional result for 1975 is 80%.) This encouraging trend would appear to be due to managerial changes which are discussed later.

THE CHANGING ROLE OF CATTLE

In contrast to upland farms with their much higher proportion of arable land, hill farms must depend on sheep as the basic enterprise. Nevertheless, cattle have an important subsidiary part to play both on technical and economic grounds. Not only has there been a dramatic increase in numbers but a change in managerial attitude. In the early post-war years there was a tendency to regard the few cows there were as "mowing machines" to improve the grazing

TABLE 1. Basic structure of hill and upland farms in Scotland (as of June 1973)[a]

Farm Type	No. of Farms[b]	%[c]	Rough Grazings (thousand ha)	%	Breeding Ewes thousands	%	Beef Cows thousands	%
Hill	1 307	6.3	2 167	61	1 128	41.0	42	9.3
Upland	4 158	20.2	1 040	29	893	32.4	202	44.9
Combined	5 465	26.5	3 207	90	2 021	73.4	244	54.2

Average size and stocking rates at national level

	Hill Farm	*Upland Farm*
Crops and grass (ha)	38	72
Rough grazings (ha)	1 658	250
Total area (ha)	1 696	322
No. of ewes	863	215
No. of cows	32	49
Rough grazing per ewe (ha)	1.9	1.2
No. of ewes per cow	26.8	4.4

[a]The table is based on the 1968 classification of the Department of Agriculture and Fisheries for Scotland.
[b]Figures relate to full-time farming units only; crofts and other part-time units are excluded as are common grazings.
[c]Percentages relate to full-time Scottish totals.
Source: "Reclamation," *Environment and Man*, Vol. IV, eds. J. Lenihan and W. W. Fletcher. Glasgow: Blackie and Sons, 1976.

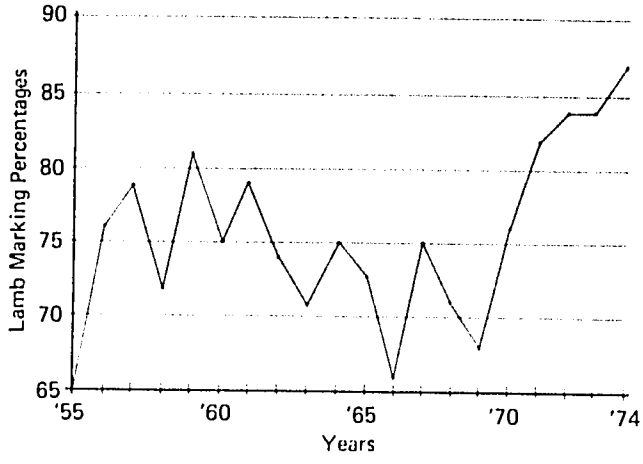

Figure 1. Average lamb crop levels on west highland hill farms, 1955-74. (Source: The West of Scotland Agricultural College, Economics Division.)

and to supply milk for the farmhouse. Increasingly over the years hill cattle have come to be regarded as an enterprise in their own right. Hill farmers have acquired a managerial expertise with cattle which was limited to a few a generation ago.

The basic financial results of eight studies of single-suckling hill herds in the West of Scotland are summarized in Table 2. As the earlier studies pre-dated the Gross Margin technique, the later years' results have been converted to the same basis, i.e., all home-grown fodder (hay or silage) includes both variable and fixed costs. Margin is thus always lower than Gross Margin, e.g., in 1969 by £7 per ton for every ton of home-grown hay fed and in 1974 with the inflationary rise in costs, by £15 per ton fed. Each year all herds were eligible for the Hill Cattle and Calf subsidies.

Despite the differing compositions of the samples, the broad trend is useful in so far as it gives a sense of perspective about the near past, which is necessary for sound judgment in the present.

TABLE 2. Trend in average margin per cow

	1951-53[a]	1960	1966	1969	1971	1972	1974[b]
				(£)			
Output	30	36	40	64	89	114	100
Less feed	13	17	19	26	32	33	82
(Vet. Med. etc.)	1	1	1	2	3	3	6
Margin	16	18	20	36	54	78	12
of which subsidy comprises	13	19	20	31	33	34	45

[a]Average of the three seasons.
[b]Estimate.
Source: W.S.A.C. Economics Division.

Until 1969 there was very little improvement in Margins which in fact were equal to the subsidy support. The difference in average Margin between the early fifties and 1969 was £20 per cow of which £18 was increased subsidy. In sharp contrast, the equivalent figures for 1969 and 1972 were £42 and £3, respectively; a much healthier position! The strong upward trend culminated in 1973 with the best season on record. Then came the beef crisis of 1974 which led to one of the worst years for the producer of weaned calves since the war. There was a tendency for some hill farmers to carry more cows than their limited in-bye land could support in terms of winter fodder. As long as calf prices were rising faster than feed costs the position was tenable, but in 1974 when prices plunged and costs accelerated, the financial consequences of the underlying imbalance of cattle numbers and fodder resources were revealed. The "fodder crisis" of 1974/75 was common to most areas of upland Britain. Hill farms in remote areas with their consequent haulage penalty were hardest hit. Herds which were wholly dependent on purchased feed had negative or at best very low Margins. (The estimate for 1974 in the table was based on the 1972 sample where most of the fodder was home grown.) In 1975, costs continued to rise but at a slower rate and the calf subsidy was reduced by £10 per head, but even with the strong recovery in calf prices, the estimated average Margin lay closer to the 1969 than to the 1971 level.

The extreme swings in the average price of weaned calves in the past three seasons illustrate the volatility of the beef situation nationally. They also indicate the difficulties, bordering on futility, of forecasting the future price of animals in store condition, during this time of transition towards full integration within the European Economic Community.

With the high cost of hay, £40+ per MT excluding haulage, the present tendency is to reduce the herd to a size more in line with home-grown feed resources. In the west of Scotland some hill farmers made the reduction in 1974/75 without any fall in gross margin by retaining the best of their draft ewes for crossing with a Border Leicester ram. At a ratio of five ewes kept for each cow culled, the gross margin from sheep in 1975 generally exceeded the gross margin foregone on cattle. The main benefit, however, was the release of capital, the essential lubricant for any move towards a new system of management. The sale of 20 cows could unlock some £3,500 which, at current costs and net of 50% subsidy would finance 3 km of fencing and 20 ha of regenerated hill land.

Excluding 1974, the keeping of a herd of suckler cows was a prudent economic exercise over the years on most hill farms, particularly the smaller units. Any new system of managing hill flocks must make

provision for hill cattle, the only other feasible enterprise.

EXTERNAL ECONOMIC FACTORS

Hill farmers are perforce "price takers" and consequently their incomes are largely determined by decisions and events far removed from the hillside. Both the hill and lowland sectors are affected by national policy decisions and changes in emphasis from commodity to commodity are reflected, sometimes sharply, back to the primary producer in the hill country. To a greater degree than the rest of the United Kingdom, Scotland still has a distinctly stratified sheep breeding industry and significant change, e.g., a shift out of sheep into barley or beef, has an effect on the whole breeding chain. However, for the majority of hill farmers outwith the Southern Uplands, particularly those in the less productive areas with lamb crops averaging around 70%, which means, after allowing for flock replacement, only 5 ewe lambs and 35 wedder lambs to sell per 100 ewes mated, the trade in ewe lambs or ewe hogs to upland farms is of little consequence. On the female side, the price obtained for the annual draft of cast (culled) ewes (18 100 mated) is of much more moment. The demand for wedder lambs is the most important single factor—subsidy support apart—influencing the hill farmer's financial year. The physical impossibility of regulating supply when demand is weak leads to fluctuations in price at auction both within and between seasons. On occasion inter-seasonal swings can be violent and none more so than in the immediate past.

The data in Table 3 relate to major sales at the main auction centers through which, in less than three months in autumn, flows a river of store livestock destined for fattening on the lowlands of Scotland and England. At some individual markets, particularly in the remoter and harder hill areas, the swings were more severe, especially the downturn of 1974. As expected, the annual variations were much stronger for breeding ewes than for wedder lambs. Despite a strong recovery in 1975, the average Blackface wedder lamb price was still 50p below that of 1973; the pure Blackface ewe, practically £2.

The pattern for weaned calves was similar, but the resurgence in prices in 1975 carried the national average above the 1973 level. The ground lost in the beef crisis of 1974 was regained in all but three markets situated in the north and west of the country.

TABLE 3. National average prices at auction, 1972–75 (£ per head)

Season	Wedder Lambs	% Change	Warranted Ewes*	% Change	Weaned Calves	% Change
1972	6.45		6.67		86	
		+38		+58		+19
1973	8.90		10.53		102	
		−28		−43		−33
1974	6.43		6.01		68	
		+31		+42		+68
1975	8.40		8.55		114	

*Ewes warranted fit for further breeding, usually 5–6 years of age and sold principally to lowland farmers.

Source: Department of Agriculture and Fisheries for Scotland.

THE FINANCIAL OUTCOME

The combined effect of a fluctuating volume of physical output due to endogenous factors and seasonal price swings due to exogenous factors originating in lowland agriculture has led, in a period of ever mounting costs, to considerable instability in profit margins despite an increasing amount of subsidy support. As has been so rightly said (Whitby, 1970) economists tend to put more emphasis on the ends—efficiency; farmers on the means—stability. The objective of government support to agriculture generally is to provide a measure of stability to farmers' returns, but, for reasons already outlined, hill (and upland) farming requires a different type of support. In Figure 2 the combined subsidies are the Hill Sheep Subsidy, the Hill Cattle Subsidy and the Calf Subsidy, all paid annually on a headage basis.

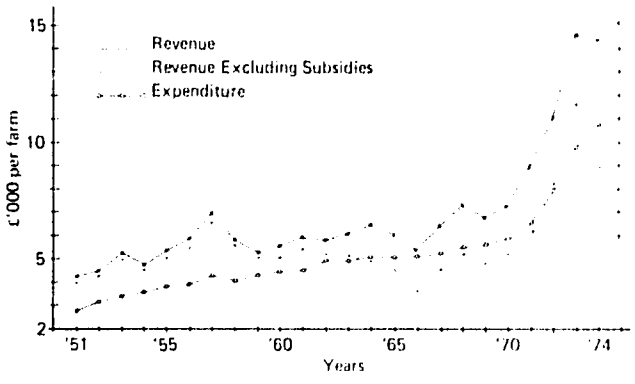

Figure 2. Trend in average expenditure, revenue and cash balance on an identical sample of west highland hill farms, 1951–74. (Source: The West of Scotland Agricultural College, Economics Division).

The long-term trend shown in the graph relates to a small but identical sample of hill farms in the West Highlands; in fact, a sub-sample of ten of those used for Figure 1. The accounts form part of the UK Price Review sample for which the agreed basis of valuation is conservative market value. As values of breeding livestock are inexorably linked to prog-

eny prices in the market place, the inflationary rise in prices in seasons '71, '72 and '73 meant that a considerable proportion of net income was due to enhanced valuations. To use net income under these circumstances could be misleading as to the amount of cash available to meet private living expenses, income tax, and savings for future investment. Using the revenue and expenditure method overcomes this problem. Also, the balance of revenue over expenditure is so predominantly in cash form that for trend purposes, it could be regarded as the cash balance. Expenditure of a capital nature is not included, only depreciation thereon.

Back in 1951 the average size of the ten farms was 1 585 hectares carrying some 1 150 Blackface ewes and 14 beef cows. The in-bye land accounted for only 24 ha of which 3 were under oats. The cereal acreage gradually declined and by 1970 not one of the farms grew oats. This trend was typical of many hill farms in the wetter west. Despite an average reduction of 10% in farm size, the ewe numbers in 1974 averaged 1 190, a marginal but encouraging improvement in average stock-carrying capacity from 1.4 to 1.2 ha per ewe. Between 1951 and 1973 the number of cows doubled.

As the difference between regions is one of degree, Figure 2 mirrors the financial fortunes of hill farming over almost a quarter of a century. A recent review (McCreath, 1976) of the total Scottish sample of some 80 hill farm accounts showed the same broad picture of profitability. When expressed in real terms, using the Retail Price Index of 1952 as a base, it was found that not until 1971 was there a better year than 1957 in terms of purchasing power; a case of 14 lean years!

The graph falls into three distinct phases. In the more profitable and stable decade of the fifties the amount of subsidy revenue was relatively small (decade mean, 6% of total revenue) and predominantly derived from cattle; the Hill Sheep Subsidy was only paid as an "income stabilizer" on three occasions and the highest rate was £0.25 per ewe. In contrast, the picture in the following decade was one of lower cash balances and general instability despite a much higher level of subsidy support (23%). The nadir was reached in 1966 when the average balance was only £300. In the last six years of the decade revenue excluding subsidy failed to cover expenditure. The first half of the present decade was dominated by two new factors. The extremely high rate of inflation due to the weak state of the UK economy is clearly reflected. In the 20 years to 1970 expenditure—rising very steadily—doubled, whereas, in the next four years it almost redoubled. The other factor, Britain's eventual if somewhat hesitant entry into the European Economic Community played a part in the inflation of product prices.

Prior to 1974 the scene seemed set for a period of expansion in profitability of a scale which would allow the average farmer some chance of investing in land improvement on a larger scale than hitherto. Then came the collapse of store lamb and store cattle prices in the autumn of 1974 which did serious damage to the confidence which had been slowly returning within the industry. As a consequence, the government announced additional aid to meet the undoubted cash crisis facing hill and upland farmers: two Hill Cattle Subsidies were paid in the one year and the Hill Sheep Subsidy was increased by £1.25 to £3.00 per ewe; hence, the highest level of subsidy revenue recorded in the period under review. For this sample the estimated cash balance for 1975 was in the region of £5,000 and the general expectation, based on the high prices ruling at present, is that this autumn's sales will show a further marked improvement. Certainly, the enactment of the Less-Favored Areas Directive throughout the EEC as from January, 1976, has removed a long felt anxiety viz the future of subsidies based on headage payments. Over the years 1970–74 the average cash balance for this sample in the less productive hill country of the West College province was £3,160 per year. After meeting private drawings and income tax provisions, it is clear that the scope for accumulating sufficient capital from within the average business to embark upon a strategic shift in flock management is fairly limited. The key to any new system is fencing and, unfortunately, unlike hill farms in the Southern Uplands, those in the Highlands generally are not ring fenced. To erect a march fence around some 1 400 ha in difficult terrain at £500 per km is a daunting prospect, financially as well as physically!

RECENT TACTICAL IMPROVEMENTS

The foregoing has dealt with the average position, but there have been considerable and impressive tactical improvements on many individual farms over the years. Apart from the relative increase in the importance of cattle, two merit special mention in the present context for they represent a movement towards the next stage of development—the two-sward system.

It is impossible from published statistics to quantify the extent of land improvement and fencing on the Scottish hills. In Argyll, a county with some 600 000 hectares of rough grazings and with the largest hill ewe population in Scotland, some 25 000 ha were improved during the late fifties and early sixties, generally in the form of mosaic regeneration. For the remainder of the decade there was little activity in land improvement (MacLeod, 1972). In the seventies there has been a trend towards the creation of "service areas" by enclosing improved

blocks for use at mating and lambing time. With the decline in the number of shepherds this innovation offers considerable logistic and technical advantages over the traditional system where a shepherd spent a considerable part of his time simply getting round the hill. The combined effect of these two improvements, it is suggested, largely accounts for the significant increase in the average lamb marking percentages in the 1970s shown in Figure 1.

THE TWO-SWARD SYSTEM

As several papers are devoted to the technical and the economic aspects of this new system, the following is restricted to the broader issues of the technique. It represents the coordination of the results of research into the fundamental aspects of hill sheep production stretching back to the early years of the Hill Farming Research Organization (H.F.R.O.). Such a biological analysis is a necessary prerequisite if a viable alternative to the traditional system is to be developed and assimilated, whether it be the two-sward or some other.

Apart from a number of pioneering hill farmers, the development of the two-sward system to date has been confined—naturally since the technique is so new—to what might be described as the "public sector":—H.F.R.O., the three Scottish Colleges of Agriculture and the Ministry of Agriculture's experimental husbandry farms in the north of England and in Wales. Consequently, there is little or no published economic data from commercially run hill farms. In order to throw further light on the technical and economic aspects, the Colleges, in consultation with H.F.R.O., are currently cooperating with nine hill farmers whose farms cover a wide spectrum of environmental conditions. This being only the second year of the project, one must turn to the public sector for key pointers and broad principles.

On the technical side, the results from all centers are impressive both in terms of increased stock-carrying-capacity and increased productivity per ewe. Two of the major constraints on increased volume of production under the traditional system have been significantly eased. The efficiency of the hill resource has been enhanced but the problem of the very limited amount of in-bye land remains and decisions on priorities as between growing green crops for fattening lambs and winter feed for cows could become more critical. Quite apart from the loss of the benefits of dual grazing, it would not seem prudent in the long term for the hill farming industry to become solely dependent on sheep.

For the industry as a whole, the picture will remain predominantly one of store production and consequent "price taking." At the individual farm level, however, there is a wide variation in the acreage (in absolute terms) and quality of in-bye land. For the larger unit on more fertile soil and, topography permitting, with scope for some extension of the lowground area, the integration of the two-sward system with a lamb-fattening enterprise has much to offer in terms of flexibility of management and marketing. The results from Redesdale Experimental Husbandry Farm in Northumberland illustrate the economic potential of this union. Assuming that a significant number of farmers in any one district successfully adopted the system, one would hope that the extra volume of sheep produced would largely bypass the store auction system.

The economic results to date are encouraging, but two points should be noted. First, the projects were initiated and the heavy capital items of fencing and land improvement well established prior to the inflationary rise in costs and the tide of product prices was rising strongly for three years prior to the ebb of 1974. If the system had proved to be uneconomic under that cost price relationship, what hope would there be for a project started in 1974? Second, the technique is new and more demanding in managerial expertise, particularly on aspects of grazing control. The scientific back-up available at these centers must have some effect—one suspects quite considerable—on the level of results achieved.

It would be imprudent to forecast, at this early stage and from so narrow a base of actual results, the likely outcome of such a radical departure from a system which has lasted for centuries. It may be too soon to be sanguine but at least one can be hopeful! Whatever the future of the two-sward system per se, one view is firmly held: the breaching of the nutritional barrier is a leap forward in hill sheep farming. Who is to know what the future ramifications of this breakthrough will be? The achievements in better land utilization attained by some of Scotland's pioneering flockmasters over the years lend support to this view.

A personal conviction based on some twenty years of working in the hill and upland sector is that the key to the future prosperity of the hills lies in considerable modification of the free range grazing tradition. The two-sward system is one of several techniques which offer hope in this direction.

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DISCUSSION

E. J. Nesius (West Virginia). I have a question that has to do with variation in prices. Do you think the subsidies are going to cause that? The fluctuation, I presume, is from the supply and demand situation, or it it just the market inequity?

McCreath. Well, since we entered into EEC it's very much more difficult to answer your question. I think undoubtedly had we not been in the EEC we would not have enjoyed these record level prices for store lambs and ewes and weaned calves. We're also enjoying a record level of subsidy support for hay. Now had we not been members of EEC this would not have happened, the support level and subsidies per head would have been reduced, because we have been able to persuade the Europeans, strangely enough, that they should adopt this system. Some economists say that this is madness, but as a man from the hill country I quite welcome it. I don't mind getting record prices and record levels of subsidy myself. But until we're fully integrated and have an agreed upon policy for mutton and lamb it's anyone's guess as to what's going to happen.

Nesius. So, are we going to have more lambs later on because of the high price now?

McCreath. Well, I can hardly tell my own clients what's going to happen at the sale next week. If I could just say one thing—there was a story told in Britain of a tremendous rate of inflation—the feed merchant informed a farmer, quoted him a price for barley and the farmer said to him over the phone, can you hold that price until I find my checkbook?

50.
Economics of Hill Land Utilization in Thailand

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The area of Thailand is about 51.4 million ha, of which 37%, or 19.2 million ha, are classified as hill land and mountains (slope greater than 30%). An estimated 49% of this hill land is located in the north and the remainder is in the central, west, east and south areas of the country where most of the land is utilized as national forest or settled agricultural land. The hill land area in the north has a potential to be used as agricultural land.

Spencer (1966) emphasized that shifting cultivation is the most wide-spread type of cropping system in South and Southeast Asia. In general, northern Thailand is characterized as a mountainous land with relatively small areas of valley land and a monsoon type of climate. The rainy season begins in May or June and lasts until October or November and is followed by a cold dry season in mid-February until the rains come again.

At present there are more than 500 000 hill tribe people in the north. They practice slash and burn agriculture for opium production or sell the cleared land to newcomers and move to a new area. Soil and climatic conditions there are very favorable for opium production (the poppy grows best in soil derived from limestone). Reports (Moorman *et al.*, 1964) indicate that the soils are red brown earths with a pH of 6 or a little higher. The soils have a blocky structure with good moisture-holding properties, and are markedly resistant to erosion even when cultivated on steep slopes. Organic content is relatively high because the characteristic structure resists leaching. Some hill folks cultivate the poppy continuously in limestone areas for ten years or more. Others practice a type of fallowing, using a swidden for perhaps two or three years, and then resting it for a similar period. Under such intense cultivation the forest rapidly disappears and savanna grasses take over the fallow land. The almost complete absence of forest is without doubt the most universal characteristic of areas where poppy is grown in northern Thailand and this is most evident in limestone areas.

In a report to the FAO in 1969, the Royal Forestry Department estimated that the total area now being cleared annually by shifting cultivation in Thailand is about 30–40 thousand ha and in northern Thailand alone, about 3 million ha, or approximately 70% of the evergreen forests situated in the most important watershed area of the country had already been denuded. These figures were obtained from aerial photographs taken in 1956–59 and must by now be considerably higher (Komkris, 1970). Shifting cultivation or shifting agriculture has destroyed vast areas of primeval forests. These forests have served

to conserve water and soil and minimize the destructive effects of floods as well as to ameliorate the local climates. The most serious aftereffects of shifting cultivation are, however, the degradation of the soil and the reduction of its capacity to adsorb and hold rain water, which results in erosion, sedimentation in streams and lakes, flash floods during the rainy season and the subsequent drying up of creeks and waterways during the dry season (Banijbatana, 1970; Komkris, 1970 and Kunstad and Chapman, 1970).

The Royal Thai government has placed important emphasis on all kinds of development for the hill-tribe people residing on the high land. However, because of differences in cultures, and economic and political problems, the projects are progressing slowly.

Under present circumstances, however, the majority of forest reserves or areas intended for reservation as permanent forests in the foothills have been heavily destroyed by illegal squatters. To turn these areas into forest by reforestation would be costly and probably cause much political faror and repercussions (Komkris, 1970). So it may be better to give up suitable areas, formerly in reserved forests and now denuded, to permanent type of cultivation and salvage what remains.

His majesty the King has personally initiated and financed projects of economic assistance to the hill tribes. These projects include field trials and agricultural extension work in villages where the opium poppy has been a subsistence cash crop for generations. The King's activities are now being complemented by the joint Thai Government-United Nations Program for Drug Abuse Control, of which an important feature is the progressive replacement of opium cultivation and the socio-economic development of village communities in certain "key" or pilot villages and neighboring "satellite" villages. Many government departments and two universities are participating in this venture.

Besides the activities mentioned above, the United States Department of Agriculture has supported agricultural research on opium substitution crops in the hill-tribe area. This project will collaborate closely with Thai-UN activities.

Several sub-projects have been undertaken for opium-substitute crop introduction, evaluation and adaptation in the selected hill land areas. The final results of these studies have not been reached. However, from the general point of view, the projects have the potential to succeed.

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DISCUSSION

Susan Almy (New York, USA). I don't know what success you're having in convincing the hill tribes to use some of these things but how would you estimate how much labor is going into the kind of crops you are trying to get them to grow compared to the profit that comes from it? Please compare that with opium and the other shifting crops that they're growing now.

Vasuvat. Well, the hill tribe people themselves have a lot of free time to work and we try to allocate only 2.5 acres of land for each family in the land settlement scheme, then the government supports their production technology through extension and soil and water conservation. The government officers convince them to use their own labor instead of equipment.

Almy. It looked to me like the system they were using, especially if they're growing opium, was giving a very high return for not much labor. Perhaps they would prefer to stay there and not work very hard rather than go on to your settlement scheme. Are you having any problems with that?

Vasuvat. This is up to the enforcement. It is well known that growing of opium is illegal. We try to convince the hill tribe people to settle in the selected area. In the meantime we conduct research on subsistence crops such as fruit trees. You may know about lichi, one of the fruit crops that can give a very good return. It is about 2 or 3 dollars per pound. Also peach and other foreign crops are quite expensive crops in our country. The introduction of foreign crops that can grow well in the north has therefore been undertaken.

Ernest Nesius (West Virginia, USA). I am interested in the diets of your people. You're trying to introduce new foods which perhaps they're not used to, is this right?

Vasuvat. No, we are not trying to introduce new foods; we want to try to make them grow the crops that can give them a good return. The foreign crops are the predominant ones; the climate suitable for such crops is present in some areas of the north. A lot of foreign fruits have been imported with a very high price in the market. Hops is also one of the imported crops for brewery business of the country. We import a lot of hops.

Nesius. What grain do you make beer out of?

Vasuvat. Imported barley.

51.
A Method for Analyzing the Contributions of Forest-Based Activity to a Region

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Increasing emphasis is being placed upon planning for regional development in all types of economies. In heavily forested areas, forest-based economic activities are often a focus for such planning efforts.

This paper explores a method for describing the effects of forest activities[1] in terms of regional economic and related social considerations. Major portions include (1) discussion of why analysis of regional impacts of forest activities is of concern; (2) suggesting that an economic and social accounting framework is a suitable context for making comprehensive, useful analysis; (3) presenting an illustrative analytical framework; and (4) discussing the importance of such an analysis to regional development problem analysis and planning. Also, previous application of the method to the Appalachian region of New York State is noted and application to other economic activities or regions is briefly discussed.

THE PROBLEM WITH FOREST ACTIVITIES AS A BASIS FOR REGIONAL DEVELOPMENT

Generally, efforts to stimulate regional economic growth and development[2] are a response to growth or development problems—the performance of a region's economy is not up to expectations. Forest activities may become a focus of planning efforts because ". . . there is a remarkably close correlation between the presence of forests and areas of economic lag" (Yoho, 1965).

But the mere presence of forests does not necessarily mean that they are a useful resource for regional development. Numerous attempts to stimulate local economies via forest-based activities have occurred in the United States. For instance, a frequent approach has been via wood utilization cooperatives; uniformly, these have neither produced significant regional uplift nor sustained themselves without large governmental subsidies (Francois, 1956 and Dempsey, 1968). Recently, there have been attempts to understand such failure. Yoho (1965) explored several possible explanations and found some evidence for each. Kromm (1972) made a similar effort, with similar conclusions. The basic conclusions of both are summarized in Kromm's statement (1972):

> As a space-using residual land use, forestry operates effectively with little competition for labor, minimal linkages with the local community, a weak regional infrastructure and questionable economic stability . . .
>
> Although forestry is an honorable and productive use of land, its advantages are severely limited. The regional benefits of forestry vary with the specific activities, ownership of the land and forests, existing economic conditions, and a host of other factors . . . The role of forestry in regional development is not as positive as conventional wisdom implies.

Both experience and rationale indicate that a forest endowment is not, by itself, necessarily an adequate

[1] A forest activity is defined as any forest resource use or management function which has the potential to generate economic or social impacts, either immediate or delayed, on all or some of the people of a defined region.

[2] In both general economic theory and regional economics, the term *growth* usually refers to *increases* in the output of an economy's goods and services (Kindleberger, 1965). The term *development* means more (Dunn, 1971); it implies progress toward some desired social state. Thus regional development may be defined as a process wherein economic or other social changes generate desirable effects on the welfare of individuals or groups within a particular region.

basis for regional development.[3] As stated by Kromm above, a "host of other factors" are influential as well.

Since the resource potential of forests for regional development is so unclear, careful analysis should precede any effort to use them as development stimulants. There are two basic questions: (1) What is the present role that forest activities play in the region in question and (2) what is the potential role that they may effectively perform in regional development efforts? Since answering the first question contributes to answering the second, analysis should proceed in that order. Methods of analysis for both these questions will be discussed, with emphasis on the first.

ECONOMIC AND SOCIAL ACCOUNTS AS A FRAMEWORK FOR DESCRIPTIVE ANALYSIS

Isard (1960) has shown that social accounts are useful components of analysis-decision models for regional planning in general, while Davis and Bentley (1967) have discussed their usefulness in problems of forest resource policy analysis. Basically, economic and social accounts are a definitional-analytical framework within which the socio-economic features of a region may be studied for purposes of problem analysis and policy formulation (Davis and Bentley, 1967; Isard, 1960).

An economic/social accounts framework promotes clarity and comprehensiveness in analysis. Also, it helps prevent value judgments (the making of which is the proper domain of the policy maker) inadvertently creeping into the analytical process (Davis and Bentley, 1967). Another advantage is that such a framework would make integrated analysis involving different disciplines (e.g., economics, sociology, political science) more feasible: the various analysts could all contribute to the analysis and interconnections between disciplines could be made clear in the process.

A METHOD OF ANALYSIS—CRITERIA AND INDICATORS OF IMPACT

Because of the usefulness of the economic/social accounts concept, it is used in suggesting a method for analyzing the impacts of forest activities on a region. The method, or analytical framework, includes (1) criteria which define the nature of a forest-based sector's impacts on (or contributions to) a region and (2) specific measurable variables (indicators) relevant to each criterion. The indicators are needed because the criteria are general defining or categorizing statements and thus are not subject to direct analysis. Data on individual indicators give partial information on the sector's or activity's impact on the region in question; data on all indicators, taken together, give a well-rounded picture of the sector's impact on the region.

The criteria and indicators are as follows (criteria are numbered, indicators are lettered):[4]

1. The amount of economic activity generated in the sector (measured by)
   a. Total employment in the sector
   b. Total annual payroll in the sector
   c. Total value added in production in the sector
2. The productivity of the sector
   a. Labor productivity (value added per man hour of production labor)
   b. Land productivity (comparative advantage)
   c. Capital productivity (state of technology)
3. The sector's direct effect on individual welfare
   a. Hourly wages of wage rate employees
   b. Average workday and workweek, pay differentials for overtime, vacation credits and pay
   c. Annual incomes of employees (both wage rate and salaried)
   d. Social security benefits which accrue to employees, including unemployment and health insurance, sick pay, and pension fund benefits (both public and private)
   e. Working conditions, including safety conditions in the work place, emergency medical facilities and services provided, amenities provided in the work place, and other general conditions of the work place
   f. Returns to entrepreneurs and owners of equity
   g. Opportunities for job advancement
   h. Composition of work force, including age, sex, race, and skill characteristics
4. The sector's effect on regional economic stability
   a. Turnover and mortality of enterprises
   b. Permanence of employment
   c. Seasonality of industries
   d. Industry sensitivity to economic cycles
   e. Dependence on raw material and energy
   f. Mobility of sector's enterprises
5. The sector's effect on the geographic distribution of economic activity over the region
   a. Intraregional location of sector activity, both incidence and magnitude
   b. Regional fringe considerations—sector's attraction of labor and other resources from the fringe outside of the region's boundary
6. The sector's interactions with the public sector
   a. Taxes (etc.) paid to all governments
   b. Services and subsidies of all types provided to the sector by all governments

[3]The Yoho and Kromm articles focus on wood-using activities. However, Beardsley (1971) shows that the same conclusions apply to recreation, another major forest activity.

[4]This analytical framework is a refinement of that presented by Zinn (1972).

c. Special public sector—private sector interrelationships[5]

7. Characteristics and conditions of entrepreneurship in the sector

a. Characteristics—type of enterprise, including legal structure of enterprises and ownership—management characteristics (training, experience, etc.)

b. Conditions—the quality and performance of entrepreneurship in the sector

8. The sector's generation of external costs and environmental impacts

a. Pollution and similar external costs generated by sector activity

b. Modification of the physical environment as a result of sector activity

c. Aesthetic impact of sector activity

d. Short- and long-term land use and land productivity implications of sector activity

9. The secondary economic effects of the sector on the region

a. The sector's position in the region's economic base

b. Interrelationship of sector activity with that of other sectors in the region

c. Multiplier effects of sector income generation

This analytical framework is not a new departure in regional analysis; the framework makes use of existing analytical techniques rather than presenting new ones. The utility of the framework is that it provides a means by which established techniques may be applied in a coordinated, efficient and mutually supporting or cross-checking manner. For example, criterion 1—the amount of economic activity generated in the sector—may be analyzed via conventional methods of aggregate economic measurement. Analysis of criterion 9—the secondary effects of the sector on the region—is based on similar types of economic data; however, application of regional multiplier analysis or input-output analysis to the data yields added information on regional intersectorial linkages and secondary effects of sector activity. There are numerous other instances of complementary data usage throughout the framework.

IMPORTANCE OF IMPACT ANALYSIS TO REGIONAL DEVELOPMENT PROBLEM ANALYSIS AND PLANNING

The analytical framework is a method for description. Description is not of interest for its own sake. Rather, the information yielded by the framework is a necessary and important starting point for explanation, prediction, and prescription in the process of problem analysis and policy making for regional development.

Analysis of the variables within the framework yields information in an economic/social accounts format. This information may be evaluated against regional social norms and goals; thereby judgment can be rendered concerning the nature of the sector's impacts on the region. Since this evaluation is norm or goal related, it follows that a problem exists wherever the sector is performing in a manner which deviates from given standards. Whether such problems merit further analysis must be judged by predicting whether their nature and magnitude will be of significance over a future period, since problem solving can only take place in the future. If so, then the groundwork exists for detailed planning (i.e., problem analysis and solution).

There are several useful analytical techniques for regional development planning: simple projection of present conditions or historical trends, comparative cost or competitive position analysis, input-output analysis, etc.[6] The technique(s) chosen for a given analysis will depend on many things—the nature of the problem, research expertise and other resources available, time available for analysis, time horizon of planning, etc.

In any event, a comprehensive descriptive analysis, as in the framework presented above, would achieve at least three important things: (1) It would help define regional development problems, as already noted; (2) it would indicate the sort of predictive analysis needed and would imply the technique(s) to use; and (3) it would provide detailed baseline data against which to compare alternatives.

If based on a thorough descriptive analysis, problem solutions should be effective and efficient, for the analytical process which led to them should have clearly identified the significant problems and their socio-economic context. Thus, analysis of the impacts of a sector on a region contributes greatly to regional development problem identification, analysis, and solution.

PREVIOUS APPLICATION OF THE METHOD

This analytical method has been applied by Miller and Zinn (1971) and Zinn (1972) with only slight variation from the criterion-indicator framework presented above. The Miller-Zinn study produced development policy and program recommendation for New York's State Office of Planning Services, while the Zinn study focused on the rationale and analytical implications of the method.

[5] If not adequately defined under 6., a. and b.

[6] For discussion of these and other techniques, refer to Isard (1960).

In both studies, the method was applied to a 14 county region.[7] Forest activities studied by Miller and Zinn (1971) included forest management activities and the logging, lumber, veneer, hardboard, Christmas tree, and maple syrup industries. Zinn (1972) added the wood furniture and other selected S.I.C. 24 industries.[8]

Miller and Zinn preceded the impact analysis with a general descriptive analysis of the forest resources and forest activities of the region. The impact analysis was followed by competitive position analyses of each forest activity. The study concluded with policy and program recommendations for improving the contributions of the forest-based sector to the region.

Space precludes detailed examination of study findings. The impact analysis findings are summarized by Miller and Zinn (1971):

> In terms of aggregate economic activity, the timber-based sector is a minor portion of the regional economy. With its relatively low productivity, the sector has great difficulty in maintaining its place in the regional economy and in adequately remunerating the people it employs. In many respects its contribution to the region is poor—low returns to labor and other resources, poor and unsafe working conditions, and considerable discontinuity of employment and enterprise.
>
> On the other hand, the social and economic benefits it produces accrue mainly to the region's disadvantaged people. With few exceptions, they live in rural areas and have fewer economic opportunities than their urban counterparts. Many are unskilled, with very limited opportunities for employment. Thus the timber-based sector contributes significantly to the welfare of many individuals and to areas of the region in great need of economic uplift.

Based on the findings, Miller and Zinn (1971) made several recommendations. The impact and competitive position analyses indicated that no large-scale programs were needed. Rather, the recommendations were for numerous modest efforts which would improve the contributions of the sector to the region in a cost-effective manner.

The Zinn study illustrated the analytical method in depth and explained it in terms of economic theory, principles of regional development, and methods of regional analysis. This study also explained the manner in which the method contributes to the overall process of regional development planning.

[7]These included the southern New York counties of Allegany, Broome, Cattaraugus, Chautauqua, Chemung, Chenango, Cortland, Delaware, Otsego, Schoharie, Schuyler, Steuben, Tioga, and Tompkins—the "Appalachian region" of New York State, as designated in the (Federal) Appalachian Regional Development Act of 1965, amended 1967 (40 U.S.C. App. 403).

[8]Specific S.I.C. (Standard Industrial Classification) codes for coded industries included in the analysis are found in Zinn (1972).

APPLICATION IN OTHER CONTEXTS

This analytical framework is general. It was developed from general economic theory, principles, and techniques. Nevertheless, some aspects of background and context are not general. These include the context of the United State's social and economic system and a defined region.

Thus the framework is not a universal. For instance, consider a small "emerging nation" interested in a development program. In the framework, at least one important variable for this context is missing: the international balance of payments or trade. This and probably other variables would need to be added; others might be dropped.

Since a change of context may reveal gaps in this particular framework, it is not properly viewed as universal. Rather, it should be taken as *suggestive* of similar frameworks applicable to other economic activities or regions. The important idea is that a framework of economic and social accounts, however defined, is a very useful basis for descriptive analysis in regional development planning.

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52.
Land Use Patterns in Appalachia

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The Appalachian Region corresponds roughly to the mountainous area which parallels the East Coast of the United States. The area which has been officially designated as the Appalachian Region consists of 397 counties in 13 states. Located along the spiny ridges of the mountains of the same name, the area stretches southwestward from southern New York to the northern areas of Georgia, Alabama and Mississippi. Only one state, West Virginia, is completely included within Appalachia. In addition to physical location, economic, social, and political conditions were factors in determining whether certain fringe counties were included under programs administered through the Appalachian Regional Commission (Britt, 1971).

The region is, of course, diverse in both physical and other features but there are some general characteristics setting it apart as a distinct area. The topography of the area varies from hilly to mountainous, with many narrow valleys, a few broader river valleys such as the Shenandoah, and some rolling areas but relatively little flat land in contiguous units. A substantial portion is classified as plateau-land (e.g., the Allegheny Plateau in West Virginia and the Cumberland Plateau in Kentucky), but much of this land is eroded and characterized by a generally rough terrain. The Appalachian ranges are geologically old, worn mountains, but they are sufficiently rugged to have acted as a barrier to western migration for many years and to have had other impacts even to the present time. The higher peaks, in North Carolina and Tennessee, are around 2 800 meters, but generally other peaks are under 2 200 meters. Most of the land area is relatively steeply sloped. Two-thirds of the land in West Virginia, for example, has slopes of 20% or greater (Lee *et.al.*, 1976). Over half (55.7%) of the land area of the region is classified by the Soil Conservation Service as having restrictions so severe as to preclude normal cropping (Coltrane and Baum, 1965).

For much of the time since it was settled the Appalachian Region has been an economically depressed and isolated area relative to the rest of the nation (see, for example, Caudill, 1963). This type of situation is not atypical for the more hilly areas of the world. However, Appalachia also has been subject to a set of boom and bust economic cycles for the last 100 years or so due to exploitation by the industrial sectors of two of its primary resources—timber and coal—which are very sensitive to economic conditions and technological change. Timber was responsible for leading one of the earlier booms, and coal has contributed to three, including the present mini-boom. Following World War II the demand for coal declined as petroleum and natural gas use expanded and mechanization of coal mining reduced manpower requirements, leading to a chronically depressed economy and a poverty stricken population despite considerable out-migration. This situation, contrasting starkly to that of most of the rest of the nation, led to the establishment of the Appalachian Regional Commission and to specialized programs to aid the region. The energy crisis of 1973 has led to a revival in the demand for coal and, at least, an economic boomlet.

RECENT ECONOMIC DEVELOPMENTS

The long economic downslide that has afflicted Appalachia since World War II appears to have ended—whether permanently or not remains to be seen. Population in the region is increasing and there is a net in-migration (Beale, 1975; Pickard, 1975). Recently incomes have increased more rapidly than for the nation and employment has increased at about the same rate (Pickard, 1975). Unemployment in much of the region has been lower than for the nation, a sharp contrast with recent years when the region tended to have one of the higher rates of unemployment. West Virginia, for example, has averaged about a percentage point below the national average during the last year; a very few years ago the unemployment rate often was 15-20%, three to five times greater than for the U.S. (U.S. Dept. of Commerce, 1976b).

The energy crisis, which caused a revival of coal, contributed to the reversal of the economic forces but was by no means the only factor. Population had started to increase by 1968-69 due to a combination of factors. One was the development of the urban crises of the 1960s which led to a negation of the concept that megalopolis was the way to move. It was becoming apparent to many analysts and individuals that depopulation of the rural areas of the nation would not solve the poverty problems but would cause many others. Rural development programs such as those of the Appalachian Regional

Commission and changing social and cultural values worked together to make rural living more appealing (USDA, 1976). Thus the situation in the region is no longer so bleak as it once appeared to be, although many problems still remain and the region still lags in level of living, public services, and some other measures of quality of life.

LAND USE TRENDS

Land use in the Appalachian Region, as in most of the U.S., has undergone very significant changes during the last three decades, but due to the topography, to changes in economic conditions, to social and cultural patterns in the region, and to changes in technology the transformation has not been the same as in most other parts of the nation. In general, land in Appalachia has been converted to less intensive uses. Specifically, large amounts of cropland have reverted to pasture, brush, and forest while pasture has gone into brush and then to forest. An analysis of this trend was made by the Bureau of Agricultural Economics as long ago as 1935 (USDA, 1935). Of course, substantial areas of land also have moved into more intensive uses—housing, commercial, industrial, highways, etc.—although the declines in population levels had a mitigating influence on those changes, too. A recent study in West Virginia indicated that significant shifts in land use were occurring in nearly every county (State Land Use Committee, 1976).

Land in farms has declined dramatically, a trend that started around 1900 and which has continued unabated except for the 1930's. Over 70% of the land area was in farms in 1900 while only 60% was in farms in 1930, although the number of the farms increased. Less than 40% of the land was in farms by 1970. The preliminary reports for the 1974 Census of Agriculture indicate that these trends are continuing (U.S. Dept. Commerce, 1972, 1976a). Much of the land that went out of production in the earlier years was not suitable for farming—some was abandoned due to steep slopes or due to loss of productivity from erosion. Other large amounts, whole farms or parts, were purchased for timber or, in some cases, coal. Today beef cattle grazing is quantitatively the most important agricultural use of land, although orchards are important in limited areas and much of the burley tobacco of the U.S. is grown within the region. Broilers are important in the southern part of the region but these factory-like operations use little land since most of the feed is imported from the Midwest. Pork, once produced on most farms and culturally an important product, has declined in relative importance, due in part to the blighting of the American chestnut which provided mast for feed. While there still is a relatively large number of farms in the region, the number of commercial farms is relatively small; 41% of the 377 852 farms were classified as commercial farms in 1969, compared with 63% for the U.S.

Commercial farming is relatively minor in Appalachia compared with other nonmetropolitan areas in the United States, but the proportion of rural to urban populations tends to be higher. Rural residences and part-time farms account for the higher proportion of rural population. There are relatively few large cities. Only 50% of the population in Appalachia was in metropolitan areas compared with 76% for the nation. Nearly twice the percentage of the population is rural nonfarm in Appalachia compared with the United States, and more than half the farms in the region are part-time units. Less than half of the farms in Appalachia are currently classified as commercial operations compared with two-thirds for the U.S.

Land in forests has increased, especially nonfarm woodland, due to both reforestation of land taken out of farming and to the purchase by timber companies, railroads, and others of whole farms or wooded parts of farms. Two hundred years ago almost all the land in the area was wooded with mostly hardwoods. Relatively little timbering had occurred by 1870, although land had been cleared for farming, especially the valleys and less steeply sloped land (Caudill, 1963). Beginning in the late 1800's much of the standing timber, but not the land, was purchased and in the subsequent coal and war booms most of it was harvested, generally in a wasteful and destructive manner. Erosion resulted, but for the most part natural reforestation eventually occurred. Because the usefulness of the land was impaired by the operations and since it takes so long for hardwoods to reforest land, much of the cutover area was purchased for national forests. However, less than half the area was ever out of woodland at any one time, and today some 60% is wooded (SCS, 1970). Although forestry is important, the harvest of timber is far below the potential of the region. Annual growth of trees in, for example, West Virginia is about 370 million cubic feet but only some 120 million are harvested each year; of one billion board feet of saw timber 500 to 600 million are harvested (W.Va. Dept. Commerce, 1976). More of the land in the central Appalachian area is forested than is generally true for either the northern or southern areas (Coltrane and Baum, 1965; USDA, 1935).

The central Appalachian area (plus Pennsylvania) also has been (and continues to be) one of the primary coal producing regions of the country, although the proportion supplied by Appalachia is dropping as Western coal is beginning to be mined on a significant scale. About 80% of U.S. coal was produced in the region in 1963 and 70% in 1973 (Miernyk, 1975). The total 1973 regional output was about 30% greater than in 1963. Coal mining, at least deep

mining, uses relatively little surface land but its impact on land use in Appalachia has been much greater than the land directly used would suggest. Housing and other facilities for the coal towns used much of the flatter land in the narrow valleys where most of the deep mines were located, the hills were denuded of trees to provide the mine props and timbers, land was covered with waste piles of slate, subsidence occurred in many areas after mining, streams were polluted by mine drainage and coal dust. Mining also resulted in railroad and road construction in the region, attracted farmers to the mines, and had important social and cultural effects.

Recently, strip mining has become more important—some 40% of the coal produced in the Appalachian region is from surface mines compared with about half for the U.S. (Miernyk, 1975). The amount of land disturbed per ton of coal is much larger than in deep mining but is, again, small compared to the total land area. About 2% of the land area of West Virginia (122 800 ha through 1975) has been disturbed by surface mining, although in some areas the proportion is much higher (Smith, 1975). The effects of surface mining also have gone beyond the actual area disturbed due to erosion, water pollution, road damage, etc. Adequate production practices and reclamation, however, can lessen or eliminate most of those effects and can, in fact, result in more "usable" (flatter) land. Housing, industry, and other intensive uses are being developed on reclaimed land.

Land for transportation—roads and railroads—has been an important aspect of land use in the region. The extension of railroads into the region allowed the development of coal mining in the first years of this century. Road building has served a similar function in more recent years. The interstate and Appalachian development highways are currently changing land use patterns, as economic development is more likely to occur along them. Most of the earlier development of roads and railroads followed the river valleys and used relatively large quantities of the limited flatter land. Today's construction techniques allow for more direct routes through the hills, although the construction is extremely costly. Under the special Appalachian development program, more than 1 900 kilometers of four-lane highways have been built and another 1 500 are in various stages of planning and construction (*Appalachia*, 1976).

Urban use of land has not increased as dramatically in Appalachia as in other regions because until recently population was declining. However, a redistribution has occurred and in many areas considerable quantities have been converted to urban uses. Between 1957 and 1967 the urban and built-up land area increased by many hectares, according to the SCS Conservation Needs Inventory (SCS, 1970; 1971) (Table 1). One of the problems for industrial development is the lack of substantial areas of easily accessible industrial sites.

TABLE 1. Major land uses and changes in Appalachia

Land Use	Year 1958	Year 1967	Percent Change
	thousand ha		
Crops	8 817	8 012	−9.2
Pasture	6 042	5 674	−6.1
Forest	27 695	29 574	6.7
Federal non-cropland	2 786	2 631	−5.6
Urban and built up	1 895	2 250	18.7
Small water areas	194	204	5.1
Other land	3 080	2 119	−31.3
Total land area	50 265	50 265	

Source: Soil Conservation Service, 1970 and 1971. State Soil and Water Conservation Needs Inventories. Publication of each State Soil Conservation Service in: Alabama, Georgia, Kentucky, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virgina, and West Virginia.

Recreational related land uses have been increasing relatively rapidly with both public and private operations. National and state parks and forests comprise a substantial land area—some 11.4% of the land area of Appalachia is in the National Park system (U.S. Forest Ser., 1973). Campgrounds, hunting preserves, and developments around reservoirs also are important in many areas. Several ski resorts have been developed in the region, although lack of consistent snow cover has been a problem. Seasonal and second homes have been constructed in many areas, both in planned developments and on individually purchased plots. Many persons who live out of the region have bought land for recreation, speculation, or other uses.

OWNERSHIP OF LAND IN APPALACHIA

Land ownership in Appalachia underwent a transformation during this century in much the same pattern as its use changed. Since most of the area was not suitable to large-scale agricultural operations, settlement and ownership was broad-based. Pioneers moving into the region tended to settle in and clear land in the valleys while also obtaining ownership of some of the hill land, although not always (Caudill, 1963). At the time of the coal and timber development in the Cumberland Plateau of Kentucky large areas had not been claimed by private owners.

Standing timber in the last half of the nineteenth century and coal shortly thereafter became the targets of speculators and developers. Large stands of virgin poplar, oak, chestnut, other hardwoods and some conifers became attractive as the industrial revolu-

tion was taking place. The existence of coal reserves in the region had been known and as the coal in Pennsylvania and other areas close to the industrial activities was used greater attention was given to areas such as West Virginia and Kentucky although its exploitation had to await the construction of railroads and/or improvements of waterways.

Prior to construction of the transportation network, the ownership of the timber and coal became the objective of speculators who could forsee vast fortunes from development of these resources. Purchase of the land, however, would have been very expensive in both capital outlays and holding costs. The owners of the timber and coal placed little value on them because there had been no market, or only a very limited one. Speculators and investors, often representatives of lumber companies, coal firms, steel mills, etc., traveled within the region purchasing standing timber (the best trees) or mineral rights for a pittance relative to their potential values. The small sums obtained were viewed as a windfall for useless resources by landowners in the area where subsistence farming was the characteristic mode of operation (Caudill, 1963).

The purchaser did not want the land because of the initial costs and taxes they would subsequently have to pay. Purchase of only the timber or mineral rights reduced the initial capital required, subsequent opportunity costs and almost completely eliminated taxes which generally were still paid only by the landholder. The rights to millions of acres were obtained in a manner which permitted their exploitation almost whenever and however the new owners wished and with little consideration for the owners of the surface rights. In subsequent years the timber was all cut (plus that which hadn't been sold) but large amounts of coal have not yet been used. Currently the ownership of mineral rights in West Virginia is being traced so that the now valuable rights can be assessed and taxed (Margolin, 1976).

In situations, as in the Cumberland Plateau of Kentucky, previously unclaimed land was surveyed and purchased by the speculators. Subsequent to the cutting of the timber and as the population exodus occurred or as erosion ruined productivity land became relatively less valuable and lumber firms, railroads, mining companies, and others began to purchase large tracts at low prices. Now a large proportion of the land in many mineral-rich areas is owned by such firms. In West Virginia the ten largest corporate owners possess about 20% of the land and in some counties 80 to 90% of the land is in such large holdings (Miller, 1974; MacAteer, 1970). A similar situation exists in the coal producing area of Kentucky (Caudill, 1963). Typically taxes on these holdings have been low—frequently far below those paid on similar property owned by individuals.

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DISCUSSION

Wendell Berry (Kentucky, USA). When you speak of 2% of strip mined land in West Virginia, are you talking of the areas of the exposed coal seam or of the exposed ground and covered up ground?

Colyer. The disturbed land. Kentucky is quite a bit higher, I understand. I don't have any data on Kentucky; I don't know whether anybody does.

E. J. Nesius (West Virginia, USA). You spoke a great deal about the situation as it is. Do you have any answers as to how we're going to handle land use in this boom state that you predict?

Colyer. No easy answers. I think we're going to handle it because it appears to me that in this period, more and more people are interested in the problem while in the past nobody even wanted to discuss land use controls of any type. They still don't want to if you call it zoning, but they're willing to talk about land use problems. The only way it can be controlled, so that any country or any area can prevent exploitation by outside parties, is if the people living in the area are concerned enough to do something about it.

John Balasko (West Virginia, USA). Why do West Virginians, or people in the Appalachian region, tend to hold onto their land more vehemently than people in the Midwest where the land would be rented?

Colyer. You're a West Virginian. You ought to be able to answer that better than I. I'm a flatlander. It's essentially, I suppose, what was mentioned about Switzerland in some of the early discussions—it's a sense of security, it's something to go back to—you go off to Detroit but you don't know that you're not going to lose your job there. So, there's always that old place to go back to. You can shoot the squirrels and live off the land.

Gary Zinn (West Virginia, USA). Well, taxes are very low.

Colyer. Yes. Also, it doesn't cost too much to hold on to the land.

Zinn. Dale, what about the development of the highway system? In my view, this is going to thrust change upon West Virginia, in particular, very rapidly—now it's only about 4½ hours to Washington, D.C. instead of 9 to 10 hours. Would you comment on this as a stimulus to rapid land use change in the state and whether or not we in the state in general recognize and are ready to react to it.

Colyer. I don't know. My first reaction to the building of the highway was that it just provided a quicker route for people to get out. However, most of the studies show that people will travel about two hours for weekend recreation and things like that. The highways now provide people from Baltimore, Washington, or Pittsburgh with easy entry into the state. I really don't know what the impact will be, but the major impact of building them was in jobs. We see a lot of developments along them. It's certain, whether the highways are contributing or what, land prices in West Virginia are increasing more rapidly than they are in the nation and there is a tremendous demand from out-of-state purchasers. Not in the old way, of building up large blocks of land, but just for a piece of land.

53.

Rapid Adjustment Farms: A Method to Demonstrate New Crop-Livestock Technology and Farm Management in Ohio's Appalachian Counties

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In 1969, the Ohio Cooperative Extension Service initiated its Rapid Adjustment (RA) Farm Program to help promote commercial agriculture within Ohio's Appalachian counties. These whole-farm demonstrations, conducted over a five-year period, were patterned after a program originated in 1962 by the Tennessee Valley Authority (TVA) to give intensive assistance to selected farm families in the seven-state Valley Region (Pace, 1970).

The RA Program has attempted to enroll younger farm families who have a strong desire to farm, but because of underdeveloped or limited resources have low farm incomes (Anonymous, 1974). Its purpose is to demonstrate that use of superior farm technology and management techniques will rapidly increase farm income. For five years, cooperator families receive help from staff members in all applicable subject matter areas of the Ohio Cooperative Exten-

sion Service, coordinated by the local county Extension agent (agriculture). The goal is to develop full-time family farm units.

Initial cooperator farms selected for the RA program were located in the unglaciated Allegheny Plateau region of Ohio which has a temperate continental climate. Farm land here is used mainly for forage and livestock production. These farms typify underdeveloped farms in the area. In Ohio, as in the TVA region, cooperator families receive limited financial assistance to help them make the necessary adjustments in farming operations faster than might otherwise be possible.

Persons associated with RA farms in other states concur in our belief that selection of cooperator families is one of the most difficult and challenging aspects of the program. In Tennessee, Ray and Hudson (1968) state that, "The operator's managerial ability is the most difficult factor to evaluate because it is associated with his mental abilities and his psychological attributes." Stephen Allen, University of Kentucky, said they attempted to "select farms where we thought the farmer had the potential to do the right kind of management necessary to reach the optimum level of development for his farm" (Kurtz, 1972).

County Extension agents and a committee of local lay persons usually nominate farm families for the program. During a one-year probationary period which has been incorporated into the Ohio program, Extension faculty inventory the farm resources to determine if there is adequate land, capital, and management potential to form an economic farm unit. In addition, agents attempt to assess the willingness of the potential RA family to follow future recommendations. A preliminary five-year farm plan is then developed to serve as a guideline for family and farm goals. The final step is the signing of the five-year agreement which joins the family, the Ohio Cooperative Extension Service, and sponsors in the cooperative effort.

To assist the farm family make necessary farm adjustments, business and industry sponsors provide approximately $1,000 annually per farm by a combination of money, fertilizer at reduced cost through TVA, or gifts of agricultural supplies. TVA has supported the Ohio program as a part of its national responsibility to develop and demonstrate new fertilizer technology.

These farms are permitted to purchase from TVA a quantity of fertilizer that costs approximately $500 less than if purchased from local commercial suppliers. In order to bring the annual sponsorship up to $1,000, each TVA-sponsored farm also receives $500 in money or supplies annually from local business firms or community-minded individuals interested in the development of agricultural resources.

The RA program includes some farms without TVA sponsorship. A large utility, the Ohio Power Company, contributed $500 per year for two of the farms considered here. The utility contribution was matched by local sponsors. All fertilizer for these two farms was purchased locally.

This paper reports information obtained from seven farms that completed the program between 1973 and 1975. Fig. 1 locates the seven farms, six of which are within the Jackson and Belle Valley Extension Areas. Table 1 presents names, county, size, and enterprise combinations for the seven farms. Three are livestock-grain farms and four are dairy farms.

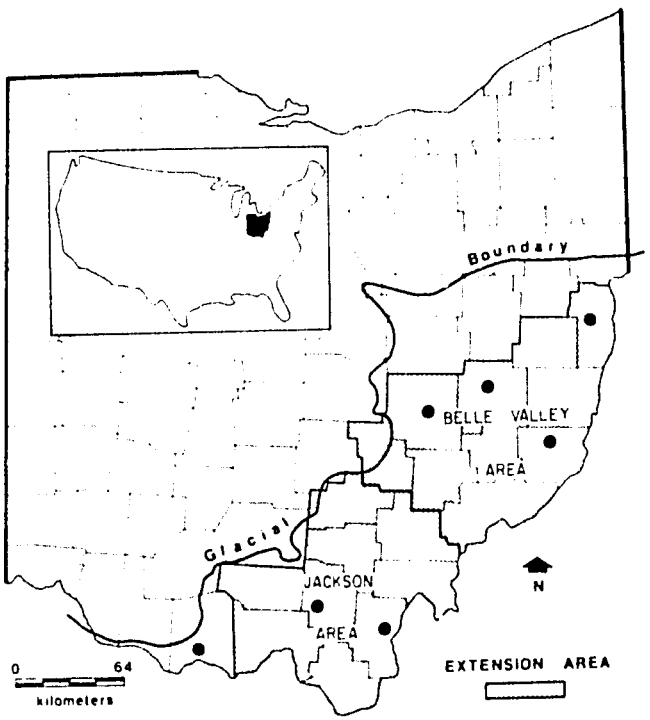

Figure 1. Seven selected Rapid Adjustment farms in southeastern Ohio.

Agronomic improvements formed the basis of progress on each RA farm. Initially, soils on these farms typically were below pH 5.5 and low in phosphorus (P). Frequently, corrective applications of potassium (K) were also required. Fertility and lime programs were developed by the area Extension agronomist conforming to Ohio State University recommendations.

Fertilizer tonnage on RA farms increased substantially during the early years in the program, then tended to plateau or rise slowly. Use of the three primary plant nutrient elements varied within the five-year interval. Cooperators consistently had been using insufficient N, so its use rose sharply at first

TABLE 1. Size and enterprise mixture on seven selected Ohio Rapid Adjustment Farms

Family	County	Farm Size Cropland & Pasture 1st Year	5th (Final) Year	Type of Farm
		ha		
E. Glenn Graham	Gallia	122	114	Livestock-grain (hogs, beef, corn)
Treber Grooms	Adams	58	78	Livestock-grain (hogs, beef, corn)
Larry McCutcheon	Muskingum	168	233	Livestock-grain (hogs, beef, corn, wheat)
Richard D. Patterson	Guernsey	82	110	Dairy
Roy J. Riegel	Jackson	87	92	Dairy
Joseph Rozsa	Jefferson	53	53	Dairy
Richard Tubaugh	Monroe	41	48	Dairy

and stabilized during remaining years. Low soil P levels (often <22.4 kg/ha, Bray P-1) required high amounts of P early, with lesser amounts for maintenance in final years. Soil exchangeable K on fields of beginning farms reflected past cropping practices. Pastures often exceeded the desired 224 kg/ha level (neutral normal NH_4OAc) while fields formerly used for hay or grains generally required corrective K. Potassium usage increased sharply on dairy farms following the reseeding of meadows to alfalfa (*Medicago sativa* L.) and orchardgrass (*Dactylis glomerata* L.). Meadows received an application of 112 kg of 0-6.2-34.9 fertilizer/ha each year for each metric ton of forage production. Most fields required 4.5 to 6.7 MT lime/ha to bring pH levels to 6.0 for bluegrass, 6.5 for other grasses, and 7.0 where alfalfa was seeded. High magnesium lime was often prescribed.

Through field demonstrations, cooperators often introduced new agronomic practices in their communities such as no-tillage corn (*Zea mays* L.), direct-seeded alfalfa without companion small grain, newer recommended forage, row crop herbicides, and the sod seeding of forages. Primary emphasis has been on proper use of lime and fertilizer in conjunction with improved weed control, variety selection, and other agronomic practices rather than solely as soil fertility demonstrations. Alfalfa yields of 9.0 to 11.2 MT/ha have regularly been obtained, with some yields up to 15.7 MT/ha. Corn yields up to 109 quintal/ha were recorded, but yields in the 75 to 88 quintal/ha range were more consistently obtained. These yields were nearly double county averages.

Farm management agents assisted with the reorganization of the farm resources into the most profitable farming system. Their planning efforts were directed toward helping the families realize a rapid and substantial increase in farm earnings.

Extension personnel in other disciplines also made important contributions to the progress of RA farms. Agricultural engineers aided in facility modernization and new construction and offered suggestions concerning farm machinery purchases. Dairy and animal scientists helped upgrade livestock enterprises. Extension veterinarians assisted with animal health programs.

Creating awareness of new and improved farming practices among cooperators and other farmers has been a major educational thrust of the RA program. Simeral (1974), in a study of the spread of agricultural technology and farm management practices outward from three of the four dairy farms of this paper, indicated, "most ideas gained were agronomic in nature and dealt primarily with fertilizer and spray programs." County agents can cite instances where farmers were directly motivated to adopt some of the practices on their own farms. More frequently, RA farms were just one of several information sources investigated by others before adopting a new practice.

Each year these and additional newer RA farms in the Jackson and Belle Valley areas have been used for tour programs to inform others. In the six years, 1971-76, over 2 500 people visited these farms. Tour groups were primarily farm families, but others who attended included local governmental, agribusiness, and agricultural credit personnel. Separate tours were conducted for vocational agriculture teachers, farm supply and equipment dealers, and USDA agency personnel since they often directly advise farmers.

Detailed farm planning which resulted in the reorganization of the business has been a significant factor in the financial progress of the RA farms. To implement the proposed changes in farming operations, all cooperators were faced with increased capital needs for permanent improvements and farm operating costs. RA farm cooperators found it easier to obtain credit needed to make the necessary farm improvements and investments when they presented the detailed farm plan to agricultural lenders.

Fig. 2 shows the average annual capital investment for the three livestock-grain farms and the four dairy farms for the base year and the five RA program years. The capital investments include all farm business assets, excluding the farmer's personal residence.

Average capital investment per farm for the livestock-grain farms was similar to the dairy farms in the base year. For livestock-grain farms the amount was $51,716; for dairy farms, $48,694. At the conclu-

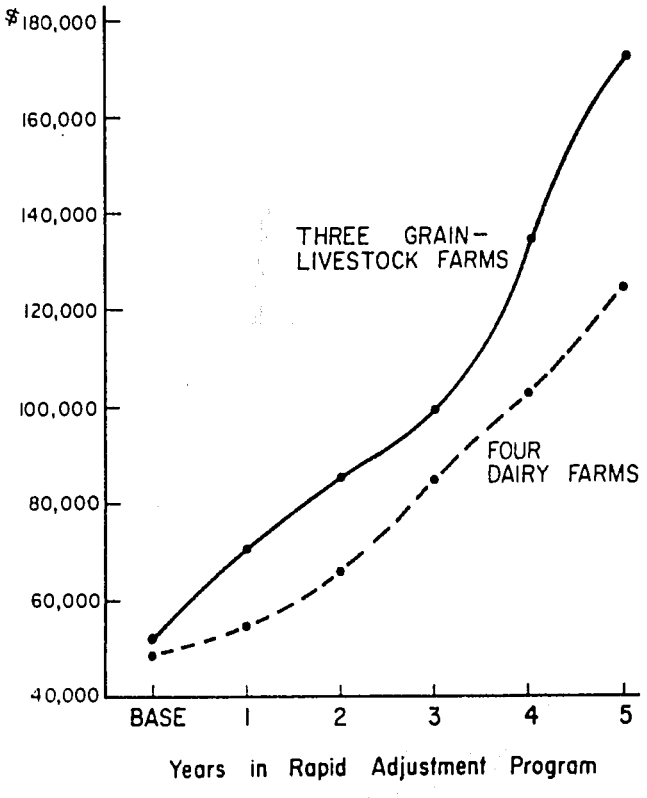

Figure 2. Average farm investment by type of farm.

sion of the five-year RA program, the average farm investment for the livestock-grain farms had increased to $171,584, while the dairy farms had an average investment of $124,425.

A summary of annual farm income in current dollars by farm type is shown in Table 2. Average income trends are given in Fig. 3. Gross income of the livestock-grain farms increased from an average of $21,619 to $65,519, with net farm income rising from $7,346 to $19,888, a 170% gain. During the same period gross income for the dairy farms rose from $24,488 to $60,228. Meanwhile the dairy farmers' net farm income increased from an average of $9,236 per farm to $13,310, a rise of 44%.

Economic reports for this time period indicate that, on the average, real incomes for the RA farms increased substantially. This occurred despite cyclical price changes and other peculiar circumstances such as the energy crisis, fertilizer shortage, and large grain exports which caused major increases in operating costs on dairy and livestock farms.

Livestock productivity, crop yields, labor availability, use of credit, and level of management were some of the factors which influenced the performance of individual farms given in Table 2. Some families achieved earlier and steadier increases in farm income than others.

TABLE 2. Farm income summary, seven selected Ohio Rapid Adjustment Farms

	Year					
	Base	1	2	3	4	5
Dairy Farms						
Gross income						
Farm A	$34,048	$32,344	$40,526	$63,450	$68,553	$84,080
Farm B	20,081	25,140	24,060	30,907	35,502	42,664
Farm C	27,482	24,543	39,689	43,378	43,185	45,166
Farm D	16,339	23,281	43,700	43,832	57,000	69,000
Average	$24,488	$26,327	$34,744	$45,392	$51,060	$60,228
Net farm income						
Farm A	$13,843	$13,192	$12,626	$26,084	$17,786	$23,851
Farm B	7,718	11,206	10,126	7,557	8,907	6,693
Farm C	9,428	3,557	7,639	18,529	11,821	7,694
Farm D	6,058	4,991	13,700	17,060	12,000	15,000
Average	$ 9,263	$ 8,237	$11,023	$17,308	$12,629	$13,310
Livestock-Grain Farms						
Gross income						
Farm A	$12,554	$17,688	$20,113	$21,725	$46,831	$65,861
Farm B	37,544	49,270	47,002	72,884	118,383	79,595
Farm C	14,759	21,829	25,942	17,944	34,667	51,072
Average	$21,619	$29,596	$31,019	$37,518	$66,627	$65,509
Net farm income						
Farm A	$ 4,715	$ 7,120	$ 7,358	$ 5,235	$22,993	$31,866
Farm B	11,557	21,615	11,427	26,521	61,134	5,270
Farm C	5,765	6,460	6,914	713	17,522	22,528
Average	$ 7,346	$11,732	$ 8,566	$10,823	$33,883	$19,888

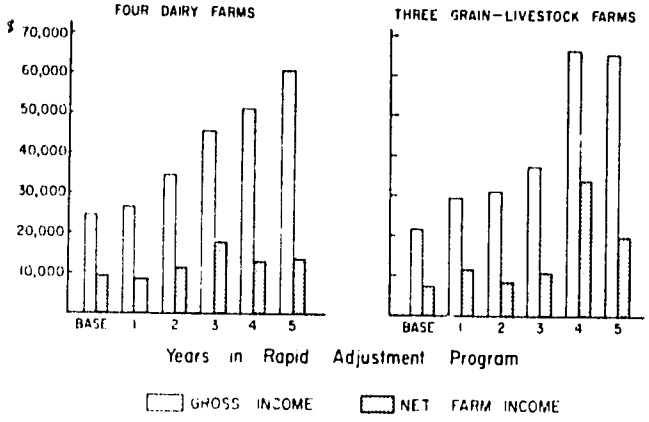

Figure 3. Farm income trends.

Dairy farms coded B and C exhibited slower increase in gross income than farms A and D and negligible improvement in net farm income during the five program years. Increased operating costs tended to offset higher farm receipts. Farms B and C made extensive improvements in dairy buildings and equipment. These changes were necessary to continue in Grade A milk production, but likewise greatly improved working conditions for both families. Farms B and C remain viable dairy operations, two or more years following graduation, despite highly competitive conditions in the dairy industry. Two years after graduation, farm B gross income increased to $55,000, although net farm income has remained below $11,000. Gross income on farm C increased to $56,000 during the two years following completion of the RA program. Net farm income increased to $12,000 the first year and to more than $22,000 the second year after graduation.

Lower livestock prices constituted the primary cause for the abrupt drop in both gross and net farm income for livestock-grain farm B during the fifth program year. The following year gross income rose to $114,570, with a net farm income of $18,530.

Charting the progress of RA farms was accomplished by setting up and adopting a detailed record-keeping system. Records provided needed information for cash flow analysis, which is also useful in predicting financial needs. Good records were often a deciding factor in obtaining needed farm credit.

Complete farm accounts obtained from the RA farm cooperators were analyzed at the end of each year by utilizing the Ohio State University Farm Business Analysis program. This year-end analysis provided information to make needed adjustments in each farm operation.

Along with attaining greater financial success and higher standards of living, the RA cooperator families at the conclusion showed overall improvement in managerial skills and improved ability to communicate with individuals and groups. In some cases families also have increased their involvement in community activities.

Extension personnel working with the RA program have gained additional confidence in making agricultural recommendations. This has helped maintain their leadership role as educators and as qualified sources of information.

Since 1971, other RA farms have been established in southeastern Ohio with key enterprises which include fruit, sheep, and containerized ornamental shrubs. Most have not completed the program, so there is no summary here. Limited experience suggests that five years is too brief a period to establish viable tree fruit enterprises. Disappointing financial performance to date for fruit farms has also been caused by recurring frost and winter freeze damage to fruit buds. The major problem with sheep has been the inability of farm operators to properly manage the rapidly expanded livestock enterprise.

Since its inception in 1969, Ohio's RA farm program has helped promote commercial agriculture within the Appalachian counties. Cooperative Extension personnel have worked intensively with a few selected farm families to demonstrate that use of recommended farm technology and management techniques can rapidly increase farm income. Success of the RA demonstration farm program is dependent upon detailed farm planning, management ability of the cooperator, adoption of recommended crop and livestock production practices, and use of complete farm business records. The program has stimulated local interest in the development of agricultural resources.

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DISCUSSION

Keith Inskeep (West Virginia, USA). You stated in your abstract that farms specializing in dairy or beef and/or swine with grain enterprises have shown most overall progress. Those with major enterprises

of fruit and vegetables and sheep have been less successful. I notice that you didn't comment on that in your presentation.

Underwood. This portion was deleted today in the oral presentation because of limited time. Our two sheep RA farms now are only just over half way through the program so no economic information from them was included. These two cooperators have developed excellent agronomic programs. Both families, however, have not been successful in the management of sheep enterprises originally predicated on rapid increase of flocks to 400–500 ewes to lamb three times within a two-year interval. Cooperators were not able to cope with these ewe numbers, so flocks are being reduced and other enterprises such as beef, vegetables, and corn production expanded.

Experience with three fruit RA farms has demonstrated that five years is just too short a period to establish a viable fruit enterprise. Local retail sales and pick-your-own was planned for production from strawberry, apple, peach, and grape plantings. Strawberries were to provide some income while grapes and tree fruits gradually came into production. High density planting of peaches and of apples grafted to dwarfing rootstalks were made to maximize early tree fruit production. Unfortunately, extreme winter cold or spring freezes have resulted in nearly complete loss of peaches in five of the last six years. Yields of apples and grapes were significantly reduced by spring freezes. Strawberries were saved from frost injury by timely irrigation. As a result, these farms have been disappointing financially even when supplemented by income from other enterprises of vegetables, grain, and livestock. Expenses would have exceeded receipts in earliest years even with favorable weather.

E. J. Nesius (West Virginia, USA). What are your plans in the future for these farms?

Underwood. We want to continue to work with RA cooperators but on a less formal and intensive basis. Our Dean of Agriculture has promised graduated farmers and wives a trip to the Tennessee Valley Region approximately two years after graduation. It encourages continued close cooperation with Extension. Four of the families reported on here took such a trip in August, 1975, where they viewed TVA fertilizer research and development activities at Muscle Shoals, Alabama, and visited RA farms in three Valley states.

54.

The Economic Implication in the Application of New Techniques to Hill Sheep Farming in Scotland

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Perhaps the most serious economic constraint on hill sheep farming in the United Kingdom (UK) is the small size of the average hill farm business. The output from traditionally managed hill sheep farms is often too low, in relationship to costs, to provide an adequate net farm income.

Though the renting of additional land, where possible, may be an attractive proposition, the purchase of additional land at present costs is unlikely to be a feasible means for a general improvement in economic status. A more widely applicable means of increasing the size of the hill farm business is by means of intensification; that is, increasing output in a way that is economically worthwhile to the farmer who undertakes it.

An analysis of the biology of hill sheep farming and a synthesis on which much of the work on intensification of hill sheep farming systems in the Hill Farming Research Organization (HFRO) has been based, has been outlined elsewhere (Eadie and Maxwell, 1975).

The key to the intensification and increase in output of hill farms in the UK is land improvement (Eadie, 1971). There exists a wide range of hill land improvement techniques, from the improvement of existing hill pastures by grazing control (only possible on some hill pastures types), to the replacement of existing vegetation by the upgrading of soils and the introduction of new species by seeding (Newbould, 1975).

Land improvement requires the investment of capital and, usually, investment in increased stock numbers also is involved. The provision of capital on the hill farm is difficult because of low income

and the high rates of interest charged on loans. There is a point beyond which the need to service the capital expenditure would give rise to short-term cash flow problems from which ultimate financial recovery would be difficult. In developing improved systems of production the economic constraints are as important as the biological constraints.

Intensification usually brings about changes in variable costs.

The intensification of systems of hill sheep production leads to a significant increase in the use of purchased cereal/protein feeds prior to lambing. The provision of homegrown feed on hill sheep farms is limited by the availability of land suitable for this purpose. Between 1962–74, the cost per unit of bought-in feed increased by at least 100%. The significance of feed costs is such that while it has been shown in HFRO studies that stocking rates can be appreciably increased by off-wintering or in-wintering, the consequent increase in feed costs cannot be sustained by the value of the increased output in current circumstances.

Land improvement brings about increases in fertilizer costs. Repeat applications of lime, to maintain suitable pH levels, and basic slag or rock phosphate to maintain adequate phosphate levels on reseeded land may be necessary every four to five years.

Intensification of pastoral systems of animal production may tend to increase the risk of disease. It is therefore important to implement a comprehensive program of disease control and this is likely to increase veterinary costs.

Improved pasture, to be effectively utilized, requires fencing, which in time will lead to increased fence maintenance costs.

Fixed costs will not usually increase as a consequence of intensification. Indeed the whole strategy is designed to spread existing fixed costs, and particularly labor costs, over a substantially larger volume of output.

The practical economic issues which have to be taken into account in the development of improved systems of hill sheep production can best be demonstrated by reference to two studies. The first relates to a grassy hill on the Organization's research station in the eastern Cheviots, and the second is on its Lephinmore station in Argyll, on blanket peat. A more detailed description of the land resources, the management and changes in output is given in a companion paper (Maxwell *et al.*, 1976).

The important initial decisions relate to the area of land to be improved, sites for improvement and improvement procedures. In the Sourhope study it was decided to limit the initial objectives to better utilization of the existing indigenous pastures. On a unit of some 283 ha a total of 80 ha *Agrostis-Festuca* pasture was enclosed over a three-year period.

Table 1 gives data on the physical and gross margin results from 1969–75, from which it is clear that there has been a considerable improvement in gross margin. Improvement in gross margin has come about by a substantial increase in the output of lamb and though costs have increased, particularly those for feed, these have been more than offset by the increase in gross output. The increase in ewe numbers also has contributed significantly to increased output.

In presenting the financial results of the studies the gross margin analysis has been done on the basis of fixed prices and costs at 1974–75 levels. This removes the effect of the variation in prices and costs which took place over the period. A realistic between year comparison can then be made of the changes in the value of the inputs (variable costs) and the changes in gross output.

However, gross margin analysis is of limited value as a means of judging the viability of a project in which capital has been invested. It provides a useful means of assessing the likely impact of improved output on net farm income but it does not provide information on the impact of the various changes on the liquidity of the business. A cash flow analysis is necessary for this purpose (Table 2). This analysis has been done using the prices and costs prevailing in each of the years of study. This provides a true basis on which the investment program can be assessed.

The increases in output achieved from 1969–73 in this study were obtained as a result of limited capital investment in fencing.

The net annual cash flows become positive in the third year. The maximum overdraft occurred in the

TABLE 1. Physical and gross margin results—Sourhope Development, 1969–75 (all at 1974–75 costs)

Item	Pre-1969	1969	1970	1971	1972	1973	1974	1975
Ewe numbers	387	398	451	518	528	573	600	601
Total weight of lamb weaned (kg)	5732	7785	9189	14178	14046	14193	14329	16042
Gross output (£)	4737	4375	5104	7173	7289	8094	8219	8633
Variable costs (£)	957	1822	2601	2013	2451	2733	2787	2459
Gross margin (£)	3780	2553	2503	5160	4838	5361	5432	6174

TABLE 2. Cash flow analysis (£)—Sourhope Development, 1969–75 (using actual prices and costs)

Item	1969	1970	1971	1972	1973	1974	1975
Change in gross margin	−655	−587	874	1050	2062	1443	2394
Capital	474	180			35	1792	337
Change in tax		−29	−89	−133	−98	−50	−699
Interest	36	189	314	216	75	135	25
Net annual cash flow	−1165	−927	649	967	2050	−434	2731
Balance	−1165	−2092	−1443	−476	1574	1140	3871
Valuation of extra stock							+3900

second year and had it not been for high inputs of feed in 1970, due to prolonged winter storm conditions, a positive cumulative balance would have been achieved in 1972. By 1974 the cumulative balance was such as to enable a further investment to be made in land improvement. Increases in ewe numbers were all financed out of cash flow from 1969–75. In 1975 the valuation of extra stock amounted to £3,900. Total capital invested in land improvement and fencing was £2,818.

On the blanket peat at Lephinmore land improvement has been in the form of reseeded pasture. Of the total 444 ha, 50 ha have been improved; 14 ha of it is totally enclosed reseeded pasture and the remainder is distributed in a mosaic of improved patches amounting to some 20% of the total enclosed area. (Table 3 presents the physical and gross margin data from 1969–75 at 1974–75 prices and costs.) Most of the land improvement had been completed at the start of this study and it was estimated from previous costs, prices, and investments that at the end of 1968 a positive cumulative balance had been achieved. The cash flow analysis (Table 4) takes this into account (actual prices and costs for each year used).

There has been a substantial improvement in gross margin, which has come about from the increase in output of lamb per ewe and from the increase in ewe numbers. Though feed and other costs have increased considerably these have been more than offset by the increase in gross output. The net annual cash flows have been positive throughout the period 1969–75 and the cumulative balance has increased successively over the period. In 1972 and 1973 it was possible to undertake further land improvement without incurring an overdraft. The value of the extra stock was estimated to be £2,495 at the end of 1975. Total capital investment amounts to about £5,000 at 1975 costs.

Both of these examples demonstrate the economic viability of an improved system of hill sheep production based on capital investment in land improvement in these environments. The Sourhope example, in particular, demonstrates how a relatively small initial investment can lead to a situation in which much greater investment can be made and increase in output achieved.

It became clear in the early stages of these studies that a much wider appreciation of the various factors affecting economic viability of investments in hill sheep farming was necessary, along with a ready means of examining alternative improvement strategies. Variations in levels of capital investment and the timing of investments in terms of the output required to justify such investments were examined, although the prediction of animal output in response to land improvement in a range of hill conditions can only be made in general terms. The sensitivity of the financial consequences of assumptions about levels of output, prices, and costs also required study. A program has been designed for this purpose for use on the multi-access system at the Edinburgh Regional Computing Centre using an ICL 4/75 computer. Access is by teletype (Sibbald and Maxwell, 1975). This allows an operator to make judgments about his results, change the input data and instantly compute a further set of results.

TABLE 3. Physical and gross margin results—Lephinmore Development, 1969–75 (all at 1974–75 costs and prices)

Item	Pre-1957	1969	1970	1971	1972	1973	1974	1975
Ewe numbers	205	339	361	373	384	422	433	434
Total lamb weight weaned (kg)	3050	7207	8500	10268	9924	10218	10870	9632
Gross output (£)	1703	3100	3503	3972	3949	4199	4280	4052
Variable costs (£)	685	1767	1848	1849	1918	2390	2711	2365
Gross margin (£)	1018	1333	1655	2123	2031	1809	1569	1687

TABLE 4. Cash flow analysis (£)—Lephinmore Development, 1969–75 (using actual prices and costs)

Item	1969	1970	1971	1972	1973	1974	1975
Change in gross margin	102	376	801	642	1334	665	430
Capital				100	684		
Change in tax	−43	−12	−12	−12	−35	−220	−2
Interest				8	47		
Net annual cash flow	145	388	813	546	638	885	432
Balance (£306 from 1968)	451	839	1652	2198	2836	3721	4153
Valuation of extra stock							+2495

The first section of the program deals with physical outputs and stock number adjustments. If stock numbers are to be increased, the program carries out the necessary calculations. On completion of stock number adjustments and the calculation of flock output (lambs, wool, cast ewes, etc.) the flock gross income for each year is calculated. The gross annual cash flow is then calculated. This comprises the marginal gross margin net of changes in fixed costs. The net annual cash flow is the gross annual cash flow less capital investment. The end year balance is then calculated. End year balance equals last year's balance plus net annual cash flow plus or minus interest. Interest is either "paid out" in the case of negative balances or "paid in" in the case of positive balances (this assumes re-investment). The program can also take account of tax if required.

Analyses of systems which include cattle may also be performed. At present the program can deal with a stated number of cows yielding a stated gross margin which may be varied in relation to changes in output and their associated costs of production. Cash flow and liquidity, net present value, and internal rates of return are presented.

The interactive capability of the program enables changes to be made to some of the input data, e.g., stock increase patterns, weaning percentage, levels of feed inputs, etc. When dealing with a particular case the program can be re-run at will.

The criteria used for judging the viability of projects are the total capital requirement, the period of years before positive cash flows and positive balance are achieved, the return on investment, and the ultimate increase in net farm income.

The amount of capital and the level and period of overdraft which is deemed feasible will be much influenced by the reaction of the bank manager or lending agency. They will be concerned about security, but in the UK it is not possible to define in general terms what the level of security required may be. (In terms of the project data, we have come rather tentatively to the conclusion that levels of overdraft should never exceed the immediately realizable assets, ie., the value of the stock, but this may have little relevance to the requirements of a specific lender.)

To examine and compare alternative policies for the best use of capital the net present values (NPV) are used. Because capital is invested differently in time between projects the conventional investment appraisal technique has been modified. Comparisons are made on the basis of a "notional" capital requirement which takes effect from the beginning of the project. This has been done by discounting to the project's start any capital invested at a rate which would reflect the returns on that capital during the years it is not used in the project.

The period of capital investment appraisal will depend on when the expected changes in cash flow will take place and also will be influenced by the period over which capital will have to be made available to the project. It seems reasonable in hill farming to examine periods of ten years, though in some cases where capital loans are taken, shorter periods of appraisal may be more appropriate.

In using NPV, alternative rates of return should be examined. High rates will favor projects in which most of the capital is invested early, whereas low rates will favor projects in which most of the capital is invested later. This procedure is particularly important if one project in which a large amount of capital is invested in the early years is being compared with another in which a large amount is invested much later. Such a procedure is doubly important in using the "notional" capital modification.

At the present on the basis of marginal capital investment, a rate of return in excess of 15% must be achieved for most types of investment. Investments will always be subject to risk and the estimation of risk for a project extending into the future will inevitably be subjective and the responsibility of the decision-maker (Reutlinger, 1970). It may, however, be sufficient in the case of projects which are considered to have poorer chances of success, to proceed only if substantially increased rates of return, say 25–30%, are to be expected.

Our studies of various project possibilities confirm the expectation that the relationship between the amount of capital invested, the year of investment, and the expected rate of increase in output has a major effect on cash flow. The examples in Table 5 demonstrate that though two projects may have very similar rates of return and NPV the patterns of liquidity are very different as a consequence of the different timing of investment. It might be argued that increases in output would occur earlier in Project 2, but since much of the output is generated from increased stock which is dependent in part on improved animal performance, it is unlikely.

Actual rates of stock increase depend on a number of factors: the rate of pasture improvement, current flock weaning percentages, and weaning weights. Buying in extra stock may be hazardous from the point of view of introducing disease.

Stock purchases made early in the life of a project will increase the level of capital investment and may therefore exacerbate cash flows, and the effect of purchases on bank overdraft must be considered; but early increases in stock numbers also will allow an early potential increase in output from the flock.

Though the projects are hypothetical they are by no means unrealistic. Both show the potential improvements in net farm income that might be expected from an increase in gross margin which can follow from capital investment in improved land.

On many hill farms the amount of potentially improvable land which is accessible to machinery is considerable. The major constraint to the rate at which land is improved in such a case is not a technical one; nor is it a lack of potential response in animal output. It is often simply that there is a limit to the rate at which improvement may be allowed to proceed, if negative cash flows are not to be allowed to reach levels from which ultimate recovery is extremely difficult. This is especially so where increased output depends upon increases in stock numbers which take time to generate and which result in income temporarily foregone.

Generally, comparatively small amounts of capital, invested in land improvement, for example, are more likely to involve only short periods of negative balance on overdraft and ultimately give rise to quite substantial cash flows. Large amounts of capital, on the other hand, particularly if invested all at once, can produce very difficult cash flow problems even where they give rise to quite large increases in output. High levels of capital investment must be spread over a number of years and made at times which are closely related to expected increases in output.

The various conclusions suggest a strategy of improving net farm income initially by means of comparatively low levels of capital investment. The investment, after a few years, will give rise to increasing end year balances (provided price/cost relationships remain the same); further investment can be made from cash flow. Even if the return on this further capital investment is low, it may nevertheless give rise to a large increase in net farm income.

The program also can be used to perform a sensitivity analysis. Having satisfied the objectives of a particular investment program in terms of performance targets it is essential that it be examined against changes in product and input costs. It is then possible not only to determine the solutions at fixed prices and costs but also their robustness

TABLE 5. Summary of outputs from Projects 1 and 2 (original flock gross margin (GM)—£2061)

					Project 1					
Year	1	2	3	4	5	6	7	8	9	10
Stock number	250	261	284	300	302	302	326	350	351	351
Weaning percent	70	80	90	100	105	110	110	110	110	110
Capital land improvement	500	0	500	0	0	1000	0	0	0	0
Capital stock increase	107	91	20	0	161	281	64	0	0	0
Flock GM	1882	2065	2535	2901	2954	2832	3472	3540	3729	3530
Cumulative balance	−904	−903	−1039	−228	249	−643	750	1887	3280	4487
Total discounted capital—£2084; NPV at 15%—£264; IRR*—16.89%										
					Project 2					
Year	1	2	3	4	5	6	7	8	9	10
Stock number	250	261	280	300	326	351	352	351	351	351
Weaning percent	70	80	90	100	105	110	110	110	110	110
Capital land improvement	2000	0	0	0	0	0	0	0	0	0
Capital stock increase	59	118	171	166	34	0	0	0	0	0
Flock GM	1882	2061	2421	2794	3249	2557	3677	3619	3677	3824
Cumulative balance	−2574	−2373	−2356	−2047	−1183	−1174	374	1492	2772	4277
Total discounted capital—£2317; NPV at 15%—£250; IRR—16.60%.										

*Interest return rate.

TABLE 6. Sensitivity analysis of Project 1 to a change in lamb selling price in range ±15%

Price change	+15%	+10%	+5%	0	−5%	−10%	−15%
NPV at 15% (£)	1318	961	622	264	−95	−432	−790
GM (year 10) (£)	3953	3810	3674	3530	3387	3251	3107

at varying prices and costs. Table 6 shows the effect of a change in lamb price of ± 15% for Project 1 (Table 5). This is not a dramatic shift in price but the change in the NPV of the project is sensitive to a shift of ± 5%. If the sole criterion in the choice of a project is that which makes the best use of capital, this project is unlikely to be chosen. The end result of the investment in terms of gross margin is affected by approximately ± 11% for the ± 15% shift in lamb price.

A sensitivity analysis will help to assess the degree of risk that may have to be taken into account for particular projects and in this respect may reduce the level of subjectivity that is inevitable in estimating risk.

The development of improved systems of hill sheep production in the UK is not constrained solely by biological or technical factors. An important aspect of the development of the hills is the need to service a capital investment in the initial period of the development. We believe that this problem may not be unique to hill sheep production or to the UK. If it is necessary and desirable that the hill and mountain regions of the world be used for the production of food, then consideration may have to be given to means whereby projects of this kind can obtain favorable financial arrangements in their early development.

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DISCUSSION

R. W. Brougham (New Zealand). Do you come to the conclusion that small capital inflow in the development plan, as you've outlined as being the ideal, just applies over the period of this study or would you argue that it has applied in time past? In projecting ahead you're suggesting small inputs, but will it be that way in say five or ten years?

Maxwell. I think the answer to your question is yes. I left out consideration of future trends and price-cost relationships. For the two projects which I had, hypothetical projects, one can look at the sensitivity of changes in, for example, the price of lambs, and he will see that for project number one, that a 5% change in lamb price will in fact prove that if the thing was on a capital basis it would provide a negative net present value.

A. W. Pantall (New Zealand). You mentioned a return of 15% on capital. Could you tell us what the interest rates being charged to farmers for borrowing capital is? Is that 15% over and above after interest has been charged or is that the amount of money that is going to be left that would meet interest at whatever interest rates prevail?

Maxwell. The 15% would now-of-days represent, perhaps, a slightly greater rate of interest than would have to be paid for borrowed capital. The agricultural lending agencies in the UK at the moment are asking something in the region of 13 or 14%. So that when I say we want 15% this is a means of paying back the capital and the interest if, for example, one were going to a lending agency. The projects that were given by way of example, the two that I gave—the Sourhope farm, for example, is giving well in excess of 15% and we reckon that this, over the years, has given something like an increase just over 20%. The Lephinmore one, which is in the rather poorer hill farming area, is probably giving somewhere in the region of just less than 20% but that was why I mentioned 15%.

55.
The Allegheny Highlands Project: An Experiment in Packaged, Team-Approach Technology for Hill Land Livestock Production

L. Balliet

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In March, 1970, the Rockefeller Foundation granted $498,000 to West Virginia University to be used over four years "toward the initiation of an experimental program to alleviate poverty in Appalachia." To date, the Allegheny Highlands Project represents a six-year effort to implement innovative technologies for the production and marketing of sheep and beef cattle in a mountainous area of the United States where agriculture was once strong and productive but has recently fallen into decline—in part due to mechanization not applicable to hill land farms.[1]

Organization and operations of the Allegheny Highlands Project have focused attention on four interdependent aspects of the typical livestock operation, namely: forage and crop production; livestock selection, breeding, and marketing; animal health care; and overall record keeping and farm planning. The Project has attempted to channel the latest knowledge and techniques for grassland livestock production into a package, team approach involving maximum assistance and accessibility.

As implied in Fig. 1, the Project's package, team approach is based on the assumption that the technological potential for dramatically improving returns to hill land livestock production is contained within the framework of existing agricultural agencies and institutions and that difficulties experienced by hill land farmers are largely the result of inadequate exposure to appropriate technology.

The Project field staff (agronomist, animal scientist, farm management specialist, veterinarian, and assistants) works directly with cooperating producers, with assistance from resident agricultural faculty at West Virginia University, county Extension agents, and other federal, state, and local agencies involved in the farm community. In addition, the agricultural business community has demonstrated support by donating materials such as pesticides, pharmaceutical compounds, and supplies for specialized breeding of livestock. In all, the Project's organization and operation imply an integrated systems approach to the rapid introduction and assimilation of technology beneficial to hill land livestock producers.

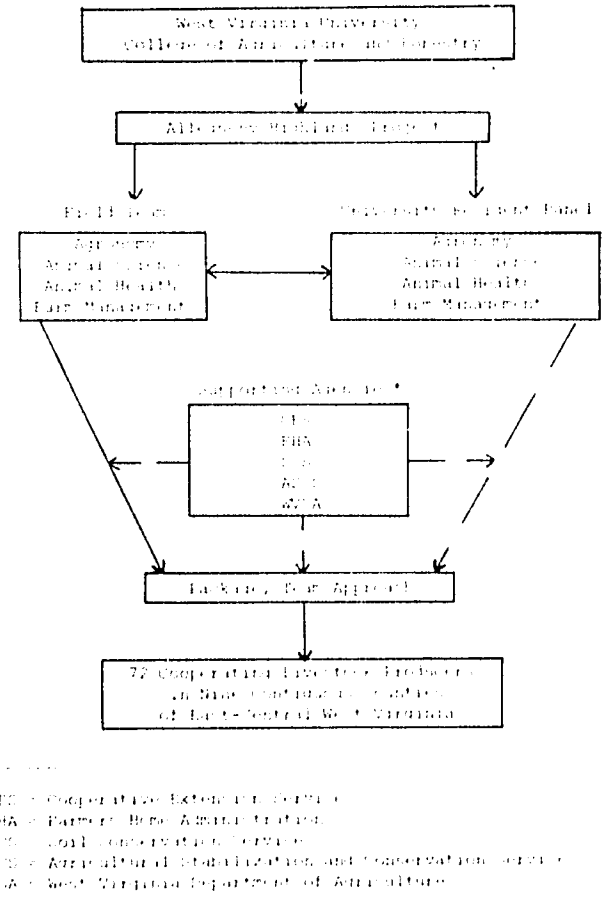

Figure 1. Organization structure of the Allegheny Highlands Project.

[1]The Allegheny Highlands Project was originally funded to operate in two east-central West Virginia counties (Randolph and Upshur). In 1975, the Rockefeller Foundation and West Virginia University re-funded and expanded the Project into seven additional counties (Barbour, Grant, Harrison, Lewis, Pendleton, Pocahontas, and Tucker) contiguous with the original two. This paper is based on an in-depth economic, social, and attitudinal evaluation of the Allegheny Highlands Project conducted by the Office of Research and Development, West Virginia University; survey and interview data collected for that evaluation provided much of the information contained in this paper.

PROGRAM EXPERIENCE OF THE ALLEGHENY HIGHLANDS PROJECT

Agricultural statistics for 1969 show the nine-county (13 146 square km) Project area with 5 390 farms, 107 500 cattle, and 77 500 sheep. Average farm size was 93 ha; average farm value was $24,366. The value of all farm products sold in 1969 in the Project area was $19,091,651—an average of which approximately 50% was derived from sales of livestock and livestock products.

Project cooperators are chosen from farm-resident males, preferably under age 40 but not over age 65, located in the project area. Cooperators must have at least 20 ha of open land suitable for forage and crop production and must be committed to owning at least 20 animal units (100 ewes or 20 beef cows, or a combination of ewes and cows) within a year of joining the Project. While participating in the Project, cooperators agree to "apply new methods, new technologies, and new ideas [with] the purpose of increasing income, reducing work per unit of product, removing hazards, and improving living." In theory, the farm improvement program developed for each cooperator involves coordinated analysis, planning, and integration of the four areas of production and management mentioned above. In practice, as described below, some areas have received more attention, with better results, than others.

Forage Activities

Members of the Project field staff have spent considerable time with cooperators and other agricultural groups, promoting better soil management and agronomic practices. Most cooperators had never tested their soils on a regular basis. Few had had their hay and pasture production analyzed for species and nutritional content. Little attention had been paid to keeping accurate weather records. The Project's forage program has provided these and other services virtually cost-free and, with assistance from the Agricultural Stabilization and Conservation Service, the Agricultural Research Service, and the Soil Conservation Service, has succeeded in greatly increasing producer awareness of the need for continuing sound agronomic management systems. As a result, forage and crop yields have increased as much as 40% but, partially as a result of unfavorable weather conditions and rapidly rising costs of lime and fertilizer, have fallen short of Project goals.[2]

Livestock Production and Marketing Activities

In spite of a drop of approximately 50% (from a high of over $130/q) in feeder cattle prices between 1973 and 1974, which created severe financial hardships for beef producers, substantial progress has been made in livestock production and marketing in the Project area. On the average, cooperators have expanded their herds and/or flocks by 11% (from 1 761 to 1 951 animal units). Qualitative improvements include the purchase of some 40 superior beef cattle and 200 ewes and rams, greatly enhancing the caliber of breeding stock. In addition, several cooperators have replaced "purebred" operations with planned programs of crossbreeding. Performance testing records from cooperators' herds and flocks indicate that kg of marketable calf/lamb per cow/ewe have increased for some producers as much as 20% over the last five years.[3]

Although the Project has not attempted to alter basic market mechanisms in the area, it has worked to enhance the position of producers in the traditional marketplace. Sheep producers are now selling lambs by telephone auction through a three-state marketing cooperative. Project staff also have been instrumental in the reorganization of livestock associations and the renovation and operation of stockyards in one county.

Animal Health Care Activities

At the outset of the Project, many cooperators were faced with serious animal health care problems. Initial efforts were devoted to the most immediate and critical situations, with the intention that the value of preventive health care practices would be most obvious and readily adopted by those producers with a crisis at hand. Simultaneously, a comprehensive program of disease prevention was disseminated on a continuing basis among Project cooperators. Steady improvement has occurred in the use of routine health care measures, especially in the control of internal and external parasites. Recently, however, this trend has slowed, due, in the opinion of field staff, to cooperators' efforts to cut costs during a time of higher supply and lower market prices.

In addition, considerable research and demonstration effort has been devoted to particularly difficult problems in the Project area, such as control of foot rot and a rare "brain worm" (*Parelaphostrogylus tenuis*) carried by white-tailed deer which, when contracted by sheep, severely damages the nervous system.

[2]During the first five years of Project activities, cooperator corn grain and corn silage yields showed some improvement, averaging 76.5 q/ha and 42.6 MT/ha, respectively. Hay yields increased from an average of 5.3 MT/ha in 1971 to 7.1 MT/ha in 1975.

[3]In 1975, Project herds and flocks produced an average 176.8 kg of calf/cow and 49.4 kg of lamb/ewe. The range of weights from individual producers was 137.4 kg to 220.0 kg for calves and 29.0 kg to 85.7 kg for lambs.

Record Keeping and Farm Planning Activities

Cooperators are obligated to participate in a detailed system of data collection and computer analysis—Electronic Farm Accounting (ELFAC)—covering inventory, receipts and expenses, crop production, livestock production and use, and family living expenses. Records kept by each farmer are used to prepare income tax summaries, operating statements, and comparative business statements.

Although record keeping and farm planning activities are considered vital to the overall program, the Project has been relatively unsuccessful in these areas.[4] Survey and interview data indicate that because the Project was without a full-time farm management specialist for nearly four of its first five years, the absence of continuity in farm management activities fostered the mistaken impression among many cooperators that record keeping and farm planning were less important than forage/crop, livestock, and animal health care programs. In addition, the sensitivity and reluctance of cooperators to disclose their personal and farm business finances to a quasi-governmental project was apparently exacerbated by personnel turnover and the resulting lack of trust that only time and close personal relationships can build.

Additional Activities

The Project staff has attempted to promote and disseminate the Allegheny Highlands "philosophy" in the larger agricultural community through various additional activities. Well-attended public "field days" emphasizing innovative technology and general farm education have been held on the farms of several cooperators. Informational displays have been developed for use at agricultural meetings and at public events such as state and county fairs. Finally, considerable time and effort have been devoted to field research, demonstration, and education (speaking engagements, etc.) both in and beyond the Project area.

SOCIAL AND ATTITUDINAL IMPACT OF THE ALLEGHENY HIGHLANDS PROJECT

The ultimate objective of the Allegheny Highlands Project is to enhance the economic and social welfare of the farm community.[5] Thus, livestock producers are assisted in adopting new technologies, where success depends heavily on sociocultural factors related to but not directly involved in the physical processes of production. For example, such attitudinal intangibles as self-image, optimism about the future, and personal satisfaction from work are concrete indications not only of previous experience but also of present and future performance. In these respects, the Allegheny Highlands Project has apparently made a significant impact among its cooperators and in the larger farm community as well.

Field studies show that over the last five years, confidence levels regarding the possibility of building a successful livestock operation have increased for cooperators and are now higher than those of non-Project farmers. The expressed amount of personal satisfaction derived from farming also has increased. On the whole, cooperators feel that their reputations as farmers have improved as a result of association with the Project. More than one-fourth state that they are now more active in agricultural community affairs. Several have become involved in area agricultural organizations for the first time, some being elected or appointed to office.

Closely associated with matters of image, personal satisfaction, reputation, and involvement has been the influence of Project activities and personnel on cooperators' families. A majority of cooperators feel that the Project has been beneficial in this respect, especially among their children. A number of cooperators state that, as a result of contact with the Project, their sons and/or daughters have decided to pursue careers in agriculture.

While not explicitly noted in the Allegheny Highlands Project's program literature, the goal of removing traditional barriers to the acceptance of new agricultural technology has been implicit in its demonstration approach. Rural residence and farming as a way of life are widely held values in Appalachia, and obviously many are farming as much for personal satisfaction as for profit. One important achievement of the Project has been to demonstrate that these two goals need not be mutually exclusive. At this point in the experience of the Project and its cooperators, increases in both income and satisfaction have been evident in specific

[4] Although all cooperators agreed to furnish basic operating data, many have been lax in doing so. Several have failed to provide sufficient data for even minimum ELFAC analysis; one cooperator provided virtually no data between 1970 and 1975. The Project also failed to meet its commitment to develop appropriate farm plans for cooperators; less than ten plans were completed between 1970 and 1975.

[5] When the agriculture portion of the Allegheny Highlands Project began, West Virginia University initiated a community development phase for the Project. Programs involving emergency medical services, the arts and humanities, and waste disposal were undertaken by local citizens' groups with assistance from various departments of the University. For a discussion of this effort, see H. Peter Marshall and Robert W. Miller, *The Challenges of a Community Development Role for the Public University* (Morgantown, West Virginia: Office of Research and Development, West Virginia University, 1976).

areas such as agronomic and animal health care practices. The ultimate aim is to engage these same attitudes and values in an integrated systems approach to livestock agriculture.

AGRICULTURAL COMMUNITY DEVELOPMENT

The Allegheny Highlands Project was intended to have a "spread" effect, accruing benefits to individuals and organizations not directly involved with Project program activities. The Project appears to have made substantial progress in this respect.

The adoption of new practices by producers not associated with the Project attests to its impact in the larger agricultural community. Survey data indicate that, statewide, some 40% of livestock producers have derived benefits from the Project. In general, both the number of producers benefiting and the level of benefits received have been directly related to proximity to the Project area. In particular, the Project has been widely credited with the introduction and adoption of effective commercial preparations for control of internal and external parasites in beef cattle and sheep. The use of these compounds has spread throughout the state. Likewise, but to a lesser extent, the Project has hastened wider adoption of improved agronomic and livestock breeding practices.

Increased awareness, approval, and acceptance of innovative approaches to livestock agriculture also are indicated by the improved image and reputation of the Project and West Virginia University. Since field activities began, both the Project and the University have gained status among livestock producers, especially in the Project area, indicating greater respect for the scientific and technical principles which both institutions represent.

The total cost of the Allegheny Highlands Project (approximately $700,000 over its first five years), although extremely high when considered only from the standpoint of services to some 70 cooperators, has probably been more than equaled in tangible and intangible returns to all who have benefited from it.[*] The Project has clearly contributed to the development of a more productive and viable livestock industry in West Virginia.

[*]County extension agents throughout West Virginia (excluding the Project area) estimate that in 1975 approximately 2000 of the state's 15000 livestock producers realized "considerable" benefits as a result of Project activities and that another 4000 producers realized at least "some" benefits. Assuming "considerable" to be $50 per year and "some" to be $10 per year, these "spread effect" benefits alone have equaled the annual cost of the Project.

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DISCUSSION

Roy Blaser (Virginia, USA). I think such a project has a potentially high value. I've just returned from Uruguay where four universities in a consortium are trying to stimulate activity with packages of information. I think your project and your paper could be most useful if you would summarize clearly and distinctly how such a project might be successful. I think you owe it to the public to carefully and clearly document that so that others working in this kind of an arena might have a better chance of success.

Balliet. I am not an agricultural specialist; I am a social scientist and a labor economist, but I spent a year examining and working with the Allegheny Highlands Project and ended up very excited about its potential. I think the potential for the project and similar projects depends on two factors.

First are policy commitments to provide research and resources at the federal, state, and local levels supporting the interests of small-scale agriculture. It seems futile to invest time, effort, and resources at the local level to assist small farms or hill land farmers when national policies are operating to drive these same producers out of the agricultural sector.

The second factor which I believe to be critical to the success of the AHP and similar development projects is close contact between the research team and the producers themselves, thus facilitating accessibility to technological expertise.

56.
Forage Improvement in Appalachian Ohio Through Sod Seeding

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For years livestock farmers in the rolling hills of southeastern Ohio have been seeking an improved method to renovate pastures and meadows to increase animal-carrying capacity. Their need was to improve low-producing forage stands on slopes up to 18% or more in this unglaciated Allegheny Plateau region of Appalachia without the possibility of the severe sediment erosion so often experienced when soil is completely tilled. Fig. 1 indicates the portion of Ohio involved in this study.

In early 1973, the Ohio Cooperative Extension Service introduced the newly developed Ohio sod seed or no-tillage forage establishment system after Paraquat (1,1′ -dimethyl—4,4′ -bipyridinium dichloride), a key herbicide in the Ohio system, was granted tolerance level and later received label for use with forages. The other herbicide employed, 2,4-D, already had label for application on forages. Paraquat labeling made sod seeding a new agronomic practice that could be adopted by farmers. In addition to minimizing soil erosion, sod seeding also has lower power and labor requirements than conventional forage renovation techniques. Costs per ha have been comparable to conventional methods when Ohio custom rates were charged for needed field operations. The sod seed educational program concerned the introduction of superior cool season grasses and legumes into sparse, weedy bluegrass pastures to improve forage yield and quality. This system was also recommended as a way to periodically reseed legumes into grass stands to reduce need for application of nitrogen fertilizer.

Sod seeding research, begun in 1964 at the Ohio Agricultural Research and Development Center (OARDC), Wooster, by 1970 had evolved into a workable ten-step management system (Myers and Triplett, 1973; Myers *et al.*, 1974; VanKeuren and Triplett, 1972; and VanKeuren *et al.*, 1972). Briefly the steps are: selecting the field to ensure that seeded species are compatible with the soil type and drainage, and that vegetation present can be suppressed or killed by the herbicides used; soil testing to determine soil nutrient levels; applying needed lime and fertilizer; close grazing or clipping; applying 1.1 kg active 2,4-D/ha 7 to 10 days ahead of applying 0.55 kg active Paraquat plus nonionic surfactant/ha; seeding with a no-tillage drill with press wheels in April–early May or August–early September; and grazing or mowing after forage seedlings are at least 7 cm tall to reduce the competition of original vegetation regrowth to the new seeding. Two remaining steps prescribed for future years are: rotational grazing and fertilizing annually to maintain a productive forage stand.

The senior author became involved with the new practice through participation in eight of fifteen initial OARDC on-farm trials established between 1970 and 1972. The junior author, then County Extension Agent, Agriculture, in Carroll County (Fig. 1), helped establish four other research trials during the same period. Eighty percent of the research trials were rated successful (40 or more plants of introduced species/m^2).

Following these initial on-farm trials, the forage sod seed educational program was initiated early in May, 1973, when the Ohio Cooperative Extension Service and Chevron Chemical Company personnel began a program centered around supervised farm

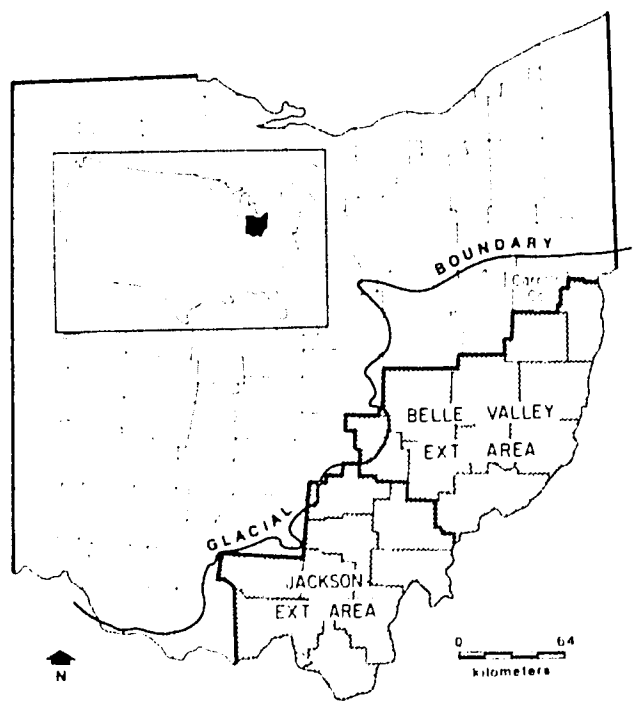

Figure 1. Extension areas in southeastern Ohio where this forage sod seed educational program has been conducted since 1973.

demonstrations to teach the management system to farmers, Extension workers and Soil Conservation personnel and other agency professionals working with farmers, and local agri-business suppliers and farm credit personnel (Underwood *et al.*, 1974). As time progressed, other agri-business firms (both proprietary and cooperative) became involved to further the program's success.

The sod seed educational program included supervised farm demonstrations, farm tours, winter schools, mass media, and individual contacts.

The area agronomist worked closely with the county agricultural Extension agents to select farm cooperators. The Ohio ten-step sod seed management system was followed. Each farmer provided the seed of forage species he wished to sow, the required fertilizer and lime as determined from soil test, and most of the herbicides. The farmer also was responsible for the separate applications of the 2,4-D and Paraquat herbicides. Chevron supplied use of a Midland Mfg. Co. Zip Seeder at no cost, plus part of the Paraquat and surfactant for smaller trials. Both spring and August seedings were made.

Seedings, 0.4 ha in size, were made using two seeders in 13 counties in southeastern Ohio during the 1973 season. Eighty-five percent were rated successful (> 40 plants of introduced species/m^2). More than 700 persons attended seven farm tours, while an additional 500 learned about sod seeding that winter during forage schools. Several implement dealers were so impressed they acquired the franchise to sell the Zip Seeder.

Four Zip Seeders were available during the spring of 1974. This permitted more Extension demonstrations of larger size (up to 4.0 ha). By fall, at least one trial was established in each of 18 of the 19 counties in the two Extension areas. Over 85% of trials were rated successful. That summer 1000 persons visited seedings while 300 more received instruction at winter schools.

By 1974, interest in sod seeding had fostered the following developments: Soil and Water Conservation districts and Production Credit associations began purchasing Zip Seeders for rental use; dealers started making drills available for rental use; A.S.C.S. practices were developed for cost sharing of no-tillage seedings; and farmers were starting to make seedings with sod drills or modified no-tillage corn planters without direct Extension Service or industry supervision. Extension agents used mass media effectively to create additional awareness of this new technology.

Further opportunity to show the effectiveness of sod seeding to improve larger land units came during 1974 when the Ohio Cooperative Extension Service started the Fertibull program. This program was designed to demonstrate maximized cow-calf production from well-fertilized 24.3-ha pasture units managed as a year-around grazing system. Nine of the fifteen farms selected for the program were in southeastern Ohio.

A minimum of 25 spring calving cows and one bull were to be maintained solely from forage produced on the unit. A heavy calf at weaning was encouraged by selection of early calving cows bred to superior bulls along with proper herd management. Pastures were increased in fertility through applications of lime, phosphorus, and potassium where needed according to soil tests. In some instances extensive removal of brush and trees was necessary prior to pasture renovation. Some units did not require complete reseeding where acceptable forage stands existed. The Tennessee Valley Authority and local agribusiness firms cosponsored the Fertibull demonstrations with Extension.

Sod seeding was the primary method used to reseed pastures on eight of the nine Fertibull units, with most reseeding accomplished during August and early September, 1974. Very favorable precipitation resulted in generally excellent stands. These larger trials provided an opportunity to measure forage production from sod seedings.

The approximately 14.6 ha of summer pasture on each farm were sown to a mixture of orchardgrass (*Dactylis glomerata* L.) and either red clover (*Trifolium pratense* L.) or alfalfa (*Medicago sativa* L.). Summer pasture was divided into three or four approximately equal-sized fields for rotational grazing from late April into early November. Any additional production not needed for grazing was harvested as hay. This was either field-stored for July–August use or barn-stored for emergency winter feed.

The 9.7 ha of winter pasture were sown to tall fescue (*Festuca arundinacea* Schreb.) and either red clover or alfalfa. First growth and some second growth on winter pastures was field-stored in round bales for feeding during late winter. Regrowth was rotationally grazed before allowing animals access to baled hay.

Winter pastures were evaluated in November, 1975, to see if forage supply would meet expected needs. Information gained also was used to determine if there was sufficient forage to permit addition of more cows. Harvested hay was determined by bale count multiplied by average weight per bale. Standing forage yield was determined by harvesting growth at several randomly selected locations in pastures within a 61-cm^2 metal frame. Forage within the frame was hand-clipped and weighed. The yield in metric tons of hay equivalent (12% moisture)/ha was determined from the oven dry weight of a subsample. The results from six Fertibull units—three where winter pastures were all sod seeded, two conventionally seeded, and one where both establishment methods were used—are shown in Table 1.

TABLE 1. Available winter feed as estimated in November, 1975

Cooperator	County	Seeding Method	Hay Equivalent of Regrowth Plus Baled Field-stored Hay
			MT/ha
Caldwell	Gallia	Sod seeded	4.6[a]
Mickey	Harrison	Conventional (1973)	4.8[a]
Gloeckner	Meigs	Conventional	5.0
Cargill	Carroll	Sod seeded	5.6
Duvall	Belmont	Part conventional/ part sod seeded	6.7
Burkhart	Washington	Sod seeded	7.6
Avg.			5.7

[a]Pasture regrowth partially grazed prior to sampling.

Actual number of cow-days of feed was closely related to these November projections. Greater legume percentage resulted in highest yields at the Burkhart and Duvall sites. All production was well above the 1.7 to 2.2 MT/ha typically obtained from unimproved pastures in this portion of Ohio (Anonymous, 1957). Both seeding methods gave comparable results.

It was not practical to evaluate forage production for the Fertibull summer pastures in the same manner. Cooperators kept records of grazing intervals in summer pastures and the number and age of grazing animals and periodic weights of animals. Calculations of expected consumption based on size and age of beef animals indicate equal or greater production per ha from the orchardgrass-legume summer pasture than from the winter pastures seeded to tall fescue-legume mixtures.

The six Fertibull units listed in Table 1 had a total of 87.4 ha of summer pasture which provide 168 days of pasture for 159 cows, 134 calves, and 5 bulls. (Artificial insemination was used on one farm.) Cow weights remained constant through the summer grazing period. Calves averaged 56.8 kg at the onset of summer grazing, gained 108.5 kg average, thus were weaned at an average of 165.3 kg. Eighty of the calves were weaned near October 1, with the remaining 54 about November 1. The summer pastures on the six farms produced 22117 kg of feeder calves, maintained the herds, and additionally produced 95.9 metric tons of hay stored for winter feeding.

During the 1975 season, more no-tillage forage seedings were made, especially in counties where rental equipment was available. Additional producers adapted no-tillage corn planting equipment to seed forages. Tours of Fertibull demonstrations figured prominently in the summer 1975 educational program. Twelve hundred persons attended tours or winter forage schools during the year.

In April, 1976, 13 sod seed demonstrations of 2.4 to 7.4 ha were established on farms in 12 counties using the new John Deere Company Powr-Till seeder. This was the first new drill specifically developed and sold by a full-line domestic farm equipment manufacturer. Amchem Products, Inc., a producer of 2,4-D, as well as John Deere and Chevron, cooperated with Extension in these trials. Good initial stands were achieved at all locations. Extreme drought during April and May caused stand loss after emergence at five sites where original vegetation was vigorous. Seedings that failed were reseeded in August as a part of the follow-up educational tours. Rental Midland Zip Seeders were available in ten southeastern Ohio counties this season. Additional farmers purchased their own sod drills or used corn planters to seed forages.

Through this educational program people have seen that sod seeding can be successful if all steps in the management system are followed. Successful results on several thousand ha attest to this fact. Today, the economic situation in the livestock industry has reduced farmer investment in grassland renovation; therefore, there is presently only a limited amount of reseeding activity. Many producers report they will utilize the no-tillage system for future renovation.

Persons who have participated in the educational program have seen a new agronomic practice become widely accepted within a three-year period. Producers now realize they can reseed forages on steeply sloping areas to improve quality and quantity of production without severe soil loss. This program, with excellent industry support, is another example where the Cooperative Extension Service rapidly and effectively took land-grant research to the people who could benefit from its use.

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DISCUSSION

A. W. Pantall (New Zealand). You mentioned you used 2,4-D and as a separate application which you had to apply several days before you applied the Paraquat. That, to me, seems an extra operation; therefore, I would like to know why you had to use the 2,4-D, the type of weeds you hope to control, and was there not another chemical which you could apply at the time you applied the Paraquat in order to cut out that extra operation? Also, please give me some idea of the cost of these field operations, herbicides, and the drill rental.

Underwood. We suggest the 2,4-D ten days to two weeks prior to sod seeding to remove plantain (*Plantago* sp.), dandelion (*Taraxacum officinale* Weber) ragweed (*Ambrosia artemisiifola* L.), and similar perennial broadleaf weeds which, under our conditions, provide considerable early competition to the young legume and/or grass seedlings. The Paraquat is applied as a second broadcast application close to planting time. Ohio research has shown this sequence to be the most effective. The interval is needed for the 2,4-D to be translocated before the desiccant, Paraquat, is applied. I understand combining a half rate of Paraquat with 2,4-D early, followed by the remaining Paraquat at planting time, is another approach being tried in Pennsylvania to achieve more complete kill of initial vegetation. Comparative costs of sod seeding to conventional ways are similar if average 1975 Ohio custom rates are assigned to field operations using typical herbicide prices:

Some Production Credit associations and Soil and Water Conservation districts are renting Midland Zip Seeders for less than $17.30/ha. This comparison does not include fertilizer or seed.

Tim Taylor (Kentucky, USA). I'd like to say that in Kentucky the John Deere Powr-Till Seeder costs about $39.54/ha, and that's with Paraquat. Not included are seed and fertilizer. Now I would like to go back to the herbicides if I may. We have a similar "how to do it" recommendation in Kentucky and we go into more detail about herbicides. We think you should only use herbicides in narrowly defined situations. The 2,4-D would be defined; you wouldn't use it under certain conditions and we would try to define that—likewise for Paraquat. We do think that we might reduce the cost considerably if we used livestock to do the grazing of the weeds and did not use the herbicide.

Underwood. Thank you. I failed to note that the initial development work on the John Deere Powr-Till Seeder was done at the University of Kentucky. One Soil and Water Conservation District in Ohio is renting its John Deere seeder at $17.30/ha, excluding tractor. There are cases, as Dr. Taylor notes, where with proper grazing management you can eliminate some herbicides. We find that many Ohio farmers will not properly manage animal rotational grazing well enough to achieve satisfactory no-tillage seedings. I feel our recommendations will be revised and with greater detail when additional herbicides such as Roundup become labeled for no-tillage forage establishment. Roundup has looked very promising in research trials. Banvel may be substituted now for 2,4-D, but it has to be applied at least 21 days prior to sod seeding or it can be phytotoxic to forage seedlings.

	Tilled Seedbed/ha		No-tillage/ha
Land preparation (plow + 2 diskings or 4 diskings)	$49.42	Herbicides—2,4-D, Paraquat	$ 6.18 23.47
Conventional drill	14.83	2 sprayings @ $7.41	14.82
		Sod seed drill	17.30
	$64.25		$61.77

56A.
Interdisciplinary Research-and-Action in the Uttar Pradesh Hills

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G. B. Pant University of Agriculture and Technology, Pantnagar, is located in the Tarai region of northwestern Uttar Pradesh. Established in 1960, it is one of India's leading centers for agricultural research, training and extension. In 1973 the University initiated an interdisciplinary research-and-action project directed to investigating and acting on problems facing farmers in a small river valley (29°42′ N; 79°16′ E) in the hilly area of Uttar Pradesh just north of the University's campus. Led by agricultural economists, the project team also included researchers from agronomy, agricultural engineering, animal science, horticulture, plant protection, and rural sociology. The project ended its first phase in May, 1976, producing a wealth of new information and insights about rural development in the Uttar Pradesh hills.[1] However, the results thus far achieved should only be an interim step to a further policy-oriented research program. This paper discusses four priority areas for future research: (1) natural resources and group action; (2) water management; (3) forestry and livestock; and (4) alternatives to an agricultural livelihood.

THE UTTAR PRADESH HILLS

The Uttar Pradesh hills are located just west of Nepal. Historically they comprise the two regions east to west of Kumaun and Garhwal. The University's project was located in Kumaun. The hills account for 17% of the state's land area, and contain 4% of its population.[2] The terrain is rugged, with elevations from 300 m on the southernmost slopes to 8000 m in the main peaks of the Himalaya along the northern border with China. Nearly all permanent habitation lies below 3000 m. The main livelihood of the people is agriculture, which they carry out on rain-fed terraces carved out of slopes ranging from 20% to 80%. Holdings are small; three-quarters of the farmers cultivate areas of 0.6 ha or less.[3] A holding in this size group typically exists as 16 or 17 fields in 7 different locations. Average field size is 0.02 ha.[4] The principal crops are upland paddy, wheat, and *mandua* (a kind of pearl millet).

Average annual rainfall is 1091.4 mm, with a seasonal low in January (71.6 m) and a high in August (132.6 mm).[5] Rainfall is highly variable from place to place in the hills, and from year to year in the same place. The University's project rain gauge recorded annual rainfall of 472.5 mm in 1974 and 965.0 mm in 1975 in the hill study area.[6] Temperatures are in part a function of elevation. Below 1200 m winter temperatures vary from 0 to 20 C, and in summer, from 20 to 35 C. Between 1200 and 1800 m the winter range is 0 to 12 C, and the summer range is 18 to 30 C.[7] The project temperature recorder, located at 1700 m, recorded a high of 47 C and a low of −2 C in the two years 1974–75.[8]

The most striking fact about the hills is the pressure of people on the land. This seems a paradox since there are only 75 people per sq km in the hills compared to an average density of 370 in the plains of Uttar Pradesh (excluding Bundelkhand).[9] Despite the seeming sparsity of population, hill people have

[1]For a more detailed presentation of project results see: *Papers* presented at the Seminar on Regional/Area Planning and Resource Development (May 27–29, 1976), and *Rural Area Development* (May, 1976), both published by the Department of Agricultural Economics, G.B. Pant University of Agriculture and Technology, Pantnagar, Nainital District, Uttar Pradesh.

[2]Department of Agricultural Economics, "Uttar Pradesh in Statistics," G.B. Pant University of Agriculture & Technology, 1976, (61 pp.), Table 2.2.

[3]Katar Singh & K.M.B. Rahim, "Base Line Survey," Chapter 2 in *Rural Area Development*, Department of Agricultural Economics, G.B. Pant University of Agriculture & Technology, Pantnagar, May 1976, p. 16.

[4]S.L. Shah, K.M.B. Rahim & Puran Pal, "Fragmentation and Scatteredness of Holdings," Chapter 3 in *Rural Area Development*, p. 59.

[5]Department of Agricultural Economics, *op. cit.*, Table 1.2B.

[6]Om Prakash, "Problems and Strategies Related to Soils of Bhikiasen Block, Almora District, Uttar Pradesh," Paper presented at the Seminar on Regional/Area Planning & Resource Development at G.B. Pant University of Agriculture & Technology, Pantnagar, May 27–29, 1976, p. 16.

[7]Ranvir Singh, "Fruit and Vegetable Production Technology for Hills with Special Reference to Bhikiasen Block," Table 1, in *Papers* presented at the Seminar on Regional/Area Planning and Resource Development, G.B. Pant University of Agriculture & Technology, Pantnagar, May 27–29, 1976.

[8]Om Prakash, *op. cit.*, p. 17.

[9]Department of Agricultural Economics, *op. cit.* Table 2.4.

difficulty in raising enough foodgrains to meet even their subsistence needs. There are 17.6 people per ha of cultivated land in the hills; the figure ranges from 2.3 to 5.8 for the rest of the state.[10] This high man-land ratio requires that more than 90% of the total cropped area in the hills be under foodgrains.[11]

Over the last twenty years and more, hill people have sought to increase their foodgrain production by two means:

1. They expanded their net cultivated area. Between 1950-51 the man-land ratio fell from 20.4 per cultivated ha to its present level. In contrast, net cultivated area in western, central, and eastern Uttar Pradesh expanded by only 3-6% during the same period, and the man-land ratio increased. Net cultivated area as a percentage of total geographical area of the hills increased from 15% in 1950-51 to 27% in 1972-73, with resulting pressure on forest and grazing land.[12] It is apparent there is little scope for further expansion of cultivated land in the hills. In fact, this process already may have gone too far.

2. Hill agriculturists also sought increased foodgrain production by taking more than one crop from the same land. Over the same twenty-year period, 1950-51 to 1972-73, the double-cropped area in the hills increased 225%. Compare this to the plains, where double-cropping spread at less than half this rate. At present the hills have the highest proportion of double-cropped to net-cultivated area of any region in Uttar Pradesh (70.4%).[13] It is nearly twice the rate of double-cropping in the prosperous plains area of western Uttar Pradesh.

Despite these Herculean efforts, getting enough foodgrain to eat still remains the major preoccupation of most hill farmers. Farmers do not yet perceive crop yield increases as a third and potent means for them to increase their foodgrain production. Reliable crop area and production data for the hills are not available for earlier years, but it appears that hill paddy yields have stagnated over the last 20 years. Wheat yields have increased by perhaps a third over the same period.[14] It is probable that per capita foodgrain production is no greater now and possibly less than twenty years ago. Nearly all of the hill labor force is engaged in agriculture, and families derive about 65% of their income from farming activities.[15] New agricultural technologies will be the key force in the economic development of this area. Furthermore, these technologies must substitute capital and labor for land.

G.B. Pant University's research-and-action project included linear programming farm planning exercises. These showed that with ideal conditions farms under 0.6 ha could increase their returns over variable costs from the present level of Rs 938 ($106)[16] to Rs 6,254 ($709)—a 667% increase. This shows the potential. A more realistic plan reallocated land from existing foodgrain crops toward commercial crops, in the process reducing foodgrain production. This plan increased returns over variable cost by 37% and required no credit, but trading foodgrain near-self-sufficiency for more commercial cropping is a risk. A third plan appeared the best alternative for farms less than 0.6 ha. It called for use of new technologies associated with high-yielding varieties of foodgrain and commercial crops and required Rs 136 ($15) of credit. This alternative produced the most foodgrains (5.64 quintals) of any of the linear programming farm plans. Commercial crops (soybean, french bean and peas) also yielded 7.36 quintals of produce. The return over variable cost was Rs 1,747 ($198), an increase of 86% over the present situation for farmers in this size group.[17]

Information such as that provided by the University's linear programming exercises provides valuable stimulus to thought. It is also well established that effective research on hill development must go beyond modeling of relationships and making of narrow, production-oriented technical recommendations. There are three good reasons for being concerned with more than just the individual farmer decision-maker.

1. A development strategy focused on individual farmer decision-makers operating in a market economy is inappropriate. The hills, with few exceptions, support a subsistence economy, and thus market forces do not strongly support either specialization or the use of cash-based agricultural technologies.

2. A hill watershed in the Himalayas, unlike a watershed in the plains, magnifies the environmental impact of the many individual daily acts of farmers, woodcutters, grazers, lumbermen, and road-builders. The social costs of private acts may be very large, and are difficult to link to individuals' private interest.

3. The cultivated land belonging to a typical hill farm is fragmented and scattered among lands of other farms. Many land-management techniques

[10]Department of Agricultural Economics, *op. cit.*, Calculated from Tables 1.7 and 2.2.

[11]Department of Agricultural Economics, *op. cit.*, Table 1.10.

[12]Department of Agricultural Economics, *op. cit.*, calculated from Tables 1.3 and 1.7.

[13]Department of Agricultural Economics, *op. cit.*, Table 1.9.

[14]Department of Agricultural Economics, *op. cit.*, Tables 3.18 and 3.21.

[15]Katar Singh and K.M.B. Rahim, p. 34.

[16]Conversion was made at the rate of U.S.$1.00=Rs 8.82 I.C. and rounded to the nearest dollar.

[17]Katar Singh and K.M.B. Rahim, "Resource Use Plans for Representative Farm Situations and Their Evaluation," Chapter 6 in *Rural Area Development*, pp. 132-38.

must be carried out over a contiguous area, but these may require the cooperation of so many farmers that success becomes a practical impossibility.

Based on these experiences and considerations, I believe there are four areas for priority research in the Uttar Pradesh hills, and by extension, other inhabited hill areas in the Himalaya.

Natural Resources and Group Action

Compared to the plains and delta areas of the Ganges system, the natural resources of the upper parts of that system—the hills—are inherently less productive. Soils are thin and highly variable in structure, texture, and fertility, water is fast-moving and not easily managed, temperature and rainfall vary greatly from elevation to elevation, and the land is easily destroyed through deforestation and erosion. Population growth in the hills more quickly pushes against the limits of the hill natural-resource base than equivalent population increases in the plains. Current knowledge and experience in both India and Nepal suggest that in the hills the pressure of people is changing the pattern of land use. This combined with a stagnant technology and obsolete institutions is causing a progressive destruction of the natural resource base on which millions of people in both hills and plains depend.

Question: If a change in land-use away from forests and grazing land to annually cultivated and waste land is the principal cause behind the destruction of natural resources, what package of legislation, local group organization, individual subsidies, and other incentives should government adopt for the puplic and private hill lands?

Within this topic the question of group action is particularly critical. In the G.B. Pant University project, research staff largely centered their attention on the farmer as an individual autonomous decision-maker. Frequently, however, situations arise in which individuals would be better off and social costs of private actions would be reduced if people could band together. Future research should investigate the social constraints on individual action and where the real benefits of group action lie. Unfortunately, it is often the case that formation of groups, group action and the benefits therefrom do not come about because of certain difficulties or dilemmas in getting (or keeping) the ball rolling. For example:

1. Group formation will be more difficult the less the *individual benefits* exceed the individual costs and are measurable and visible to the prospective group members. An obvious example is soil conservation measures, whose benefits are hard to see in the short run.

Question: How can the benefits of group action be made more measurable and visible?

2. Group formation will be difficult *the larger the group* which is to be organized. This is especially true if the group has to include people fron different social classes, villages, or socio-economic territorial units.

Question: What is the optimum size of the group—the technical requirements of the activity vs. the social constraints on joint action?

3. If benefits cannot be limited to *just those who join* together in a common action, individuals will have no incentive to incur the cost and effort of joining the group because they will in any case benefit from group action. An example is building a village drinking water system with public taps—once it is built everyone can take water from it, even if they did not contribute to having it constructed. In this situation there is a need for some kind of legal or institutional mechanism which either limits the distribution of benefits to those who participate, or compels every potential beneficiary to participate. In the example, the public taps could be placed inside homes only of those who paid a portion of the costs of construction, or the system could be financed by a village-wide assessment or tax.

Question: How can the spill-over of benefits be limited?

4. If the benefits of common action depend on the *positive action* of every member of the group, individuals can withhold their cooperation in an attempt to maximize their share of the expected benefits. Suppose a new agricultural technology or practice will benefit all who adopt it but requires that each farmer cooperate with his neighbors. In the hills, important changes in farming behavior in even a small area will require the agreement of substantial numbers of people. One or two holdouts could, then, prevent the others from changing to an improved cropping pattern. Another example is land consolidation, which is just not feasible on a voluntary basis. Legislation and strong government follow-up may be required for the solution of this kind of group action problem.

Question: How can the problem of holdouts be handled?

5. if the benefits of common action depend on the *restraint* of every member of the group, there is tremendous temptation for individuals to "jump the gun" and monopolize the expected benefit before the others do. Suppose a good fuel and fodder tree is standing near a village. Further assume that if the tree were allowed to reach maturity judicious cutting would yield enough fuel and fodder for several families (the members of the group). But without effective restraints any family may cut the

tree before maturity, pre-empting the other families. The Kumaun forest rules were changed in 1939 in part to deal with this phenomenon. They prohibit cutting the upper one-third of the crown, or any branch over three inches in diameter. They also specify that trees are to be given a two-year rest between loppings. In this case, legislation has not proven to be effective.

Question: What kinds of sanctions will restrain group members from premature snatching of the benefits?

Water Management

The excessive speed and quantity of rainwater runoff which causes erosion and siltation of bottomlands at lower elevations has been a principal concern of the University's project staff. However, the hill farmer does not attach the same importance to this runoff because to him it appears the returns to private investment in soil and water conservation measures are uncertain, delayed, and diffuse—an accurate assessment for people with low risk-bearing capacity, fragmented holdings and no means to capture the downstream benefits of their actions.

Researchers should investigate combinations of crops, cultural practices, and engineering structures which will slow runoff and retain water more or less *in situ*, either above or below ground. At the same time, these techniques must be evaluated in costs, benefits, and uncertainty for farmers using them, other farmers in the area, and downstream irrigation and hydropower consumers. The results of this kind of research would appeal to farmers, who are first of all interested in securing stable or increased production. These results would also add to the presently scanty empirical knowledge on what kinds of land use, under what climatic conditions, contribute most to soil erosion.

Forestry and Livestock

The hill-farm watershed system includes the relationship among water, soil, plants, and land use on the public and private lands within a defined catchment area. The system also includes the social and economic forces which condition the use and management of these natural resources. Within this system, livestock and forestry are two very important interrelated elements. Livestock broaden the ability of human beings to extract food and other useful products from the surrounding vegetal resources. Livestock convert crop residues and wild vegetation gathered from an *extensive* area into (1) manure, which is funneled into a *limited* area—the cultivated land—and human benefits through the cultivated plants, (2) traction power, which supports the technology of plow agriculture and continuous cultivation, (3) milk, ghee, meat, and other animal products which are consumed or used by the farm family, and (4) live animals, milk, ghee, and other products which are sold or bartered to meet the other needs of the family.[18]

This relationship remains a happy one so long as there is sufficient wild vegetation from forests and grazing lands. However, the increasing population brings more and more land under cultivation with several consequences, among them:

1. To extend cultivation requires more animals, but extension of cultivation can occur only by inroads on the wild vegetation by which the animals are supported. Thus there is a "scissors" effect—numbers of livestock that can be supported are falling while the demand for their farm power and manure is increasing;
2. As forest and grazing lands disappear, livestock must be supported largely from the same cultivated land that supports the human population. In some sense livestock now compete with, rather than complement, the human population's food-raising activities.

Some propositions:

1. If there is sufficient wild vegetation, then the determinants of the number and kind of livestock a family will hold are:
   a. the family's level of prosperity;
   b. the kind of livestock which will produce the mix of products the family wants from the available sources of wild vegetation and crop residues;
   c. the number of family members available to look after the livestock.
2. If the area of cultivated land and the number of livestock expand and significantly reduce the area and productivity of forest and grazing land (sources of wild vegetation), then,
   a. the number, kind, and condition of livestock that a family can support decline;
   b. soil fertility declines when livestock manure is diverted for use as fuel to replace wood no longer available from vanishing forests;
   c. soil erosion increases from the marginal cultivated lands, the barren grazing land, and the denuded forest.
3. If a family has too few animals, and those in poor condition, then:
   a. soil fertility declines because there are fewer animals producing manure, and
   b. there is a decline in food and other animal products for consumption and sale.

[18] I am indebted to J. Andress for a discussion of some of these relationships as they obtained in Garhwal in 1962-63. See Andress, J., *Culture and Habitat in the Central Himalaya*, University of California, Berkeley, Ph.D. 1966, University Microfilms No. 66-8261, pp. 208-235, 273-276.

4. If soil fertility and moisture retention decline so do crop yields, resulting in less food for human beings, less crop residues for animals and, therefore, still fewer animals.

5. Forage crops and stall feeding of livestock is a solution only if:

a. farmers can no longer get enough fodder from off-farm sources;

b. area available for food and cash crops is not adversely affected;

c. little additional labor or animal power is required; and

d. there are no additional nutrient demands on the cropping system.

Alternatives to an Agricultural Livelihood

If the average hill family cannot meet all of its consumption needs from agriculture, how can government improve the alternatives to making a living from the land? The principal issues are education and employment. Off-farm employment can be found in the Forest and Public Works departments and their contractors, the military, hill-station tourism, and in a few light-industry units. These sources are inelastic in supply, and therefore members of hill families migrate to the plains, either seasonally or permanently.[19]

Questions: How can labor exchanges more effectively match people with jobs? Are labor unions a feasible means to increase the bargaining power of wage laborers? Should hill migrants be given employment preference in the plains because their removal from the hills lessens human pressure on hill watersheds which in turn reduces erosion and silt damage to plains food production systems?

Hill people in Uttar Pradesh put a high proportion of their cash surplus into the education of their male children.[20] *Question:* Should government put proportionally more of its development resources into education so that more hill children can receive more education and thus receive higher incomes for remitting to the hills once they are employed in the plains?

IN CONCLUSION

The forces of change in hilly areas of the developing world are not well understood. The question of rural development and the management of natural resources in hill areas of northern India and Nepal is particularly critical because the actions of relatively small numbers of people clearing more land for food production in the hills directly threatens food production systems of much larger numbers of people in the lower parts of the Ganga and Indus basins. There are many issues, and none has received adequate attention because plains areas have more political weight and have seemed to offer greater and more certain opportunities for technology-based development. However, it now appears that hills and plains are more intimately linked than had been thought. Investigations of the ecology, society and economy of hill areas are therefore timely.

[19] R.D. Singh and L.R. Singh, "Employment Structure and Migration of Rural Labor," Chapter 4 in *Rural Area Development*, p. 68.

[20] J.S. Sharma, Ranvir Singh and A.K. Singhal, "Consumption, Investment, and Financial Structure," Chapter 5 in *Rural Area Development*, p. 99.

57.

Crop Production of Arable and Meadow Plants at High and Low Altitudes in Norway

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The object is to give in as brief terms as possible, a general view of harvested crops in a high-altitude situation (*i fjellbygdene*) as compared with the lowland (*flatbygdene*). The area (highland and lowland) comprises a large part of the southeastern territory of our country (60-62° N). The results are extracted from many series of experiments (where all has been measured and weighed) by various experiment stations, generally within the period 1945-70.

When calculated for the central highland, the following boundaries of altitude may serve as an orientation: The lower border descends to about 300 or 350 m above sea level and rises to 700 or 750 m. Above that limit we have the mountain where the timberline has to be passed. The area beneath the 300 m border represents in my account the lowland.

The plant species which are included in the survey are barley, potatoes, roots, meadow grasses, and clover.

The experiments were principally carried out on well-cultivated land. Manuring was complete and applied with moderate intensity, and the difference in quantity between highland experiments and those in the lowland may be characterized as minor.

We then make the hardy assumption that the differences in harvested crops between upper site and lowland—or probably more correctly, the balance (which here has to be demonstrated)—has its base upon soil and climate. Then we have put some influence by man in the background, together with other more or less disputable factors. Naturally enough the greater altitude causes limitations. The limit of heights is discussed in individual sections. By choosing medium height as the base, we find that only in a few cases does yield on the lowland exceed that of the highland.

ROTATION EXPERIMENTS

The experiments were carried out during the years 1939-58. The rotation period was 6 or 7 years, in the following yearly order: 1. oats; 2. potatoes or roots; 3. cereals; and 4.-6. (or 7.) ley (not grazed).

The plots were fertilized every year: Farmyard manure, supplemented with artificial fertilizer, was applied in arable years (potatoes or roots), in the years of ley, only artificial manure. The fertilizing has varied in harmony with some difference of plans within the different fields. Yields were calculated for each and all fields (Table 1). (Content of farmyard and artificial manure are put together.)

It was of importance to have as little difference as possible in fertilizing intensity between high- and lowland experiments. Calculated as the mean for all plots, the figures seem to be suggestive of not any major difference, and should be of minimal consequence for the balance of harvested crops between the two altitudes.

Computed as Scandinavian fodder units (fu) you will find in the table a sum of the harvested results, all counted per decar and year. Group 2 should be to some degree more heavily fertilized compared with group 1.

In the valleys and on the hillsides the figures are approximately 450 fu, and at the lowland 380. If the yield in the highland is set up to 100, the lowland yield is only 80 or 90%.

The harvest in the highland is taken at 550-600 m altitude. The difference in elevation between the two levels is about 475 m (about 61° N).

In the lowland there are only trifling differences between group 1 and 2; in broad features it is more significant in the highland. In this connection I should like to underline the difference. As a rule

TABLE 1. Long-continued rotation experiments, 1939-58

Area	Altitude (m)	Kg per decar			Fu/decar		Rel. Yield		Normal May/Sept.	
		P	K	N	1	2	1	2	Rain (mm)	Temp. (C)
Highland	585	2.5	8.5	7.4	432	543	100	100	293	10.5
Lowland	110	2.4	7.7	6.4	374	378	87	83	380	13.6

our results are suggestive of rising profit by heavier manuring at rising altitude. Especially it seems to be more significant when lower sites of the valleys are compared with the upper hill and mountain slopes.

As many as 4000–4500 fu/ha/yr may not be estimated as a big yield. Variations are implied, but notice that the results are founded on a large number of experiments accomplished during a succession of years and include extreme climatical variations. Also, the fertilizing is not heavy, farmyard manure much as normal, but artificial fertilizer supplements lightly or very lightly used, compared with more modern standards. In extremely few cases, if any, has the lowland exhibited greater yields than the highland.

SOME INDIVIDUAL PLANT SPECIES

Barley

Barley has been cultivated on the hillsides from old times. The cultivation has decreased during later years. Experimental data presented in Table 2 are founded on results from the years 1945 to about 1965. The account in Table 2 is set up separately for the concerned stations and adjacent districts.

TABLE 2. Yield of barley, kg and fu per decar

		Station			Nearby Districts		
Area	Station	Grain	Straw	Fu	Grain	Straw	Fu
Highland	Loken	383	416	492	321	486	449
Lowland	Moyst/ Volleb.	325	362	419	325	363	421
Lowl./Highl. (%)		85	87	85	101	75	94

The figures originate to some degree from a time when the plant rotation management was the ruling system and new systems had not yet been widely adapted. For the following yield of barley, we refer to some figures by Magnus Jetne from experiments in the highland.

Preceding Crop	Grain Yield
Potatoes or roots	401 kg grain/decar
Meadow	347 kg grain/decar
Barley	336 kg grain/decar

Cultivating potatoes in one or two of the preceding years required well-manured and worked up soil, and created high class conditions for the following growth.

Quite another thing was the continuous cultivation of cereals for years, which for many reasons, generally of an economic nature, had been advised the last several years. The livestock had diminished and the one-sided cereal cultivation was set up as the prevalent pattern. This management had its most intense development on the lowland, but reached the lower localities in the valleys as well.

Nothing seems to suggest that the hill land should be inferior in crops of barley proportionately to soil and climate, provided suitable selections of varieties are made. The elevation of the valley and hill slopes are, of course, not without effect. Around Valdres, which very frequently in this contribution is considered as a central locality, is the experimental station, Loken, sited at 550 m altitude. Based on many years experiments and experiences, I am inclined to suggest that unfailing yields may be harvested up to 600 or 650 m altitude.

Potatoes

Data are extracted from experimental reports from Loken representing the highland, and Moystad the lowland (Table 3).

TABLE 3. Yield of potatoes, kg/decar (1940–65)

		Altitude	Yield (kg)	
Area	Station	m	Tubers	Dry Matter
Highland	Loken	550	3647	809
Lowland	Moystad	180	3165	654
Lowl./Highl. (%)			87	81

The yield at lowland is hardly in excess of 3000–3500 kg/tubers per decar. Up the valley slopes often we find 4000 kg, and 3500 kg on an average. Proportionately, the lowland has produced 80–90% compared with the highland. Apparently the hill crop balances up to the standard when referred to content and yield of dry matter as well.

In an experimental report from Loken, Erling Olsen has computed data for the years 1948–64. For the upper field group at a middle height of 750 m, the dry matter yield was still 724 kg. This figure is not far from the average yield on the lowland in the district of Moystad (Hedmark Country).

The elevation brings about naturally enough its limitations. As one passes up the valley slopes, the temperature tends to decline and the length of season of growth decreases. One should be anxious about under-maturity and decreasing dry matter content. Our results could not with any security be explained in that way—and at any rate not to any intensive degree.

Nevertheless, the rising height and its limitations may be the object of many deliberations.

I am not able to take up the many-sided problem of potato disease and to what degree the problem is related to the elevation. But the infliction called dry decay tends to weaken rapidly in the central highland above about 550 m altitude. At Loken we

had only feeble attacks and not very frequently, either. Diseases induced by other virus attacks, we don't quite get rid of—but, they occur mostly in the lower localities. Plant-louse, the infection carrier doesn't grow so intensely—and I should think that virus infections weaken to some degree with increasing altitude.

Potatoes are well known as a frost-weak plant species, and of course at the higher locations they are affected by night-frost—more frequently in our northern hill and valley slopes. We require more frost-resistant varieties, and it should be of interest to get some information about experiences and research work connected with that point and the results obtained in other exposed high altitude situations.

Roots

The experiments summarized in Table 4 were carried out during the years 1953-61 as reported by Birger Opsahl.

TABLE 4. Yield of turnips (kg dry matter/decar)

Situation	Station	Roots	Root + Leaves	% Dry matter Root	Altitude (m)
Highland	Loken	730	910	10.5	561
Lowland	Vollebekk	585	733	10.4	88
Lowl./Highl. (%)		80	82		

The fertilizing in both composition and intensity is almost identical at the two altitudes.

If the yield at the highland is called 100, the lowland must come close to 80 or 82%, and the dry matter content will be almost the same from both country levels.

It was always a pleasure for me to notice that turnip fields at Loken at 500-600 m altitude would remain green and fresh during all of September and even the first half of October. The growth was of course decreased to a rather great extent—parallel to falling temperature—but the process was not completely brought to an end.

From other experiments accomplished within the same period of years, down at the lowland with Swedish turnip (*kålrok*) as the cultivated plant variety an approximately mean yield of 800 kg dry matter/decar was attained. Compared with the results attained at the mountain localities (Table 4) this constitutes about 100% or a little more. In many experiments, also at an early period of the year, it has been demonstrated that swedes, on the basis of greater temperature and longer growing season requirement, are not able to compete with roots (turnips) up the valley slopes or in the upper mountain localities. An old rule states: Plant swedes in the lowlands and turnips on the upper sites (levels).

Meadow Crops

Results from different experimental series in the period 1948-64 are abstracted for this summary. All experiments are not planned or adjusted to be exactly parallel in time and pattern between the selected altitudes, but still the results are useful to illustrate how different heights compare in and between the Norwegian mountains.

The lowland is identified with the experimental station Moystad, and Loken the highland, with the mountain station Berset on the top of an extensive mountain plateau.

At Moystad and vicinity the experimental fields are laid out in 1-2 year ley, and for the most part harvested two of the subsequent years. The plant association is timothy and red clover.

At Loken the experimental fields are laid out in first year ley and harvested for 4-5 years. The plant association is either timothy in pure stand or as a main plant mixed with a minor part of fescue (*Festuca pratensis*), *Agrostis tenuis*, and in some cases red clover.

On the ley at Berset a corresponding seed mixture has been used. Timothy is the main plant, partly in pure stand and in some cases mixed with agrostis and fescue. The experiments are harvested up to 7 years. On the surface cultivated natural meadow fields at Berset the association of grasses consists for the most part of *Deschampsia caespitosa* and *Agrostis tenuis* with some interference by *Poa pratensis*, *Phleum alpinum*, and *Anthoxanthum odoratum* and, in addition, numbers of herbs.

The experiments in the lowland are harvested two times a year, at the highland location one or two times, and at the mountain site one cutting (Table 5).

With the most intensive fertilizing (or mean of the two most heavily fertilized plots) yield at the lowland was around 1 000 kg and at the hill land about 950. But we have cases under hill land conditions, too, where two cuttings have come up to 1 000 kg as well. On artificial meadow (ley) in the mountains, the yield is about 700 kg, and on natural meadow about 500 kg.

When proportionately computed and yield at the central highland (the Loken experiments) calculated as 100, the lowland yields were 107%, and the mountain yields approximately 80 and 57% for artificial and natural meadow, respectively.

The difference between artificial and natural meadow on the mountain has in all experiments been observed to be about 200 kg. Rarely on surface cultivated natural meadow at Berset have we been able to harvest above 500 kg hay/decar. Most frequently the yield has been lower.

From ancient times the hill farmers have had scattered small outfarms (*saetervoller*) in the mountains, where the livestock (including the pig, goat,

TABLE 5. Kg hay per decar/year (1948-64)

Station	Altitude (m)	Type of Meadow	Increasing fertilizer 1	2	3	Mean of 2-3	Comparison of 2-3
Moystad	175	Ley	790	940	1 060	1 000	107
Loken	550	Ley	761	919	947	933	100
Loken	Tim. (%)	Ley	80	86	88	87	
Berset	1,000	Ley	528	677	771	724	78
Berset	Tim. (%)	Ley	78	85	85	85	
Berset	1,000	Natural	489	512	534	523	56
Berset	Grass (%)	Natural	65	65	70	68	

and the cat) has to be moved up for 2-3 months of summer maintenance. The practice in most cases has been to manure the natural permanent grassland and, naturally enough, with farmyard manure only. In the course of the years we have had several experiments with manuring (farmyard and artificial) on that sort of surface cultivated permanent grassland. The yield has to some degree been variable, but we have scarcely managed to harvest more than 500 kg dried hay per decar. This result may also be justified, as above all it is a moderate- or low-priced management. However, some ditching and surface cultivating ought to be done.

The possibilities of increasing the number of natural cuttings and quantity of aftermath depend on many factors: time of main cutting, plant association and manuring, and, not the least, moisture. The growing season, which I have emphasized many times, decreases with rising altitude, and therefore the basis of more frequent cutting decreases. The extent of the area hinted at here has of course considerable variations. I am inclined to suppose that inside the more central hill area (the Valdres area) and up to 650 or 700 m altitude, the aftermath may provide a comparatively good yield. Connected herewith I want to emphasize that on our hill farms it is customary to graze the meadow land until late in the autumn—many places too severely I am afraid—and the aftermath is largely harvested in that manner.

Among the grass species and varieties there are differences in vegetative ability after cutting. On top of the list we have cocksfoot (*Dactylis glomerata*) with fescue (*Festuca pratensis*) not far behind. But cocksfoot has a weakness for blight (rust) fungus attack, and a low ability for wintering under upper hill land conditions, and still weaker on the mountain. The Norwegian variety, Grindstad timothy, has a medium position, with the north Norwegian varieties (Bodin and Engmo) as its weaker partners. Varieties of *Agrostis* are winterhardy, but begin growth late in the spring and have weak ability for aftergrowth. *Poa* varieties are more in the middle.

The manuring is an important factor as well. Accounted as an average for the years, the following figures show the rates of application expressed as mean values, for the two heaviest fertilized experiment plots, in kg/decar/year.

Highland Loken and Berset			Lowland Moystad		
P	K	N	P	K	N
2.9	8.3	11.1	3.3	7.1	14.6

As will be noticed, fertilizing is kept within moderate limits. For P and K it should represent a balance between the amount supplied and that carried off. Also, the difference of intensity between lowland and hill land (including the mountain) is not large; it could be estimated as nearly negligible. The greatest difference is associated with the supply of nitrogen. It represents about 25 kg nitrate of chalk, and corresponds to the extra supply for the second cutting consistently carried out in the lowland experiments. The lowland should, by the balance calculation, be profitably dealt with.

SEPARATE EXPERIMENTS

These experiments were laid out in 1962 and completed in 1967 at three altitudes, (61 N): Apelsvoll at 250 m altitude; Loken at 550 m; and Berset, at the top, exactly at 1 000 m.

We have had two parallel fields on each station, mowed and grazed alternately every second year. Cuttings were made three times a year at Apelsvoll, two at Loken, and one at Berset. Fertilizing was the same at all three stations, and the same grass varieties were seeded.

TABLE 6. Hay with 17% water, average 1963-67

	Apelsvoll	Loken	Berset
Altitude (m)	250	550	1 000
Kg/decar	687	853	625
Comparative yield	81	100	73

The yields are reported as dry matter, recalculated to hay with 17% water content (Table 6).

As an average of the five-year period, top yield has been taken at Loken, and constitutes not less than 850 kg. The harvest is less at Apelsvoll and Berset. Compared to Loken, the lowland and the mountain yielded 81 and 73%, respectively. If we consider one variety of timothy, north Norwegian Engmo, which in several other experiments has been the best on upper situations and fairly poor in the lowland, the Berset yield rises to 740 kg; compared with the same variety at Loken the relative yield rises to 92%.

As compared to the results in Table 5 the harvest is to some degree lower. At Loken and Berset the average is approximately 100 kg hay less, and on Apelsvoll (the lowland) about 300 kg. Several factors may contribute to this difference.

The drainage did not work quite to satisfaction for the Apelsvoll experiments. In addition, we had an early summer drought in one of the experimental years which acted much more intensively on the lowland than the hill land. In upper hill land and especially on the mountains, as a rule the moisture is adequate.

The plots were grazed every second year. We have experienced that grazing causes more damage on a seeded sward, compared with cutting only, particularly upon the timothy. On the mountain, with short season and cooler climate, the growing ability is weaker and more restricted than in the lowland. Consequently, the previous years of grazing may act more intensely upon the growth under mountain circumstances. Surprisingly, growth and yield have been able to compete closely under valley and lowland conditions.

Partly to compare results between experiment stations and partly to be symmetrical in time for the several manurings, one saltpeter fertilizing at Berset was made at a time when the vegetation had started well up and had reached about 15–20 cm—about mid July, and consequently in the middle of the most intense growth. The vegetation was at its most effective development, had nearly maximum assimilation capacity, and the temperature was favorable for growth. Probably this made a considerable contribution to the result at Berset in comparison both with Loken and Apelsvoll.

CLOVER AND ITS POSITION

In connection with our task, the growth of clover is of particular interest. In the first place the plant is very valuable for its feed quality, and next to that for its beneficial effect of supplementing nitrogen to the soil. But clover is also an ambitious plant species. It is therefore able to serve as an important indicator of growing potential on mountain slopes and, further, to what altitude plants may be able to endure a long winter and give yields of any significance.

The figures in Table 7 seem to suggest that growth of clover has been almost as good up to middle height in the valleys, compared with the results in the lowland experiments. By choosing 1–3 years ley as the basis, the difference between the altitudes is in some cases in favor of the hill land. In the Loken experiments the clover has been more stable from year to year. At Moystad, on the contrary, it grows excellently in the first year of ley, but is much weaker in the second and is almost gone in the third. This is much the same development we find in many other experiments in the lowland.

Otherwise there is a distinctive feature which almost continually recurs: Rising nitrogen fertilization reduces the clover component in the meadow and increases the grasses. That is a common tendency in most of our experiments. Now that greater emphasis is placed on producing bigger yields of grasses to be conserved as silage fodder, and available subsidized low-priced artificial nitrogen is abundant, we have the impression of dwindling clover in the meadows. Whether this is good or bad, I don't know, because of complex economic reasons. However, yield of grasses from artificial and natural meadows has been rising to a considerable degree.

Farmyard manure has an ability to stimulate the growth of clover. This effect has been demonstrated in many of our experiments. One or two years of

TABLE 7. Clover, component as percent of total herbage yield

Year	Area	Place	Year of Ley	N Fertilizer Level N_1	N_2	N_3	Altitude (m)
1934–58	Hill	Loken	1–3	25	20	19	550
1942–63	Low	Moystad	1–3	33	33	13	130
1952–66	Hill	Districts	1–3	32	29	28	489
1947–64	Low	Districts	1–3	18	13	10	200

N_1–N_3 rising nitrogen supplement.

cultivated farmyard manured potatoes or roots in advance of reseeding of ley should have a beneficial effect upon the clover development in following years. Because of an abundant access, farmyard manure is the only fertilizer used on the small fields of arable land, especially on the upper sites of hill land.

The winter climate in our eastern mountain territories, particularly on the east side of the Long Mountains, has considerable stability and is judged an important factor to wintering plants including clover. Deviations and variations may occur, but as a rule the autumn combined with a light cover of snow brings about a slow freezing down of the ground. The ground continues almost in that condition with a sparse or heavier layer of snow, through the whole winter. Most frequently a slow thawing occurs during the month of April and first half of May. The severe alternation of freezing and thawing during an otherwise severe winter season, which is experienced on the coast and in the north of our country, and which may be hard upon the vigor of wintering plants, occurs less frequently.

The altitude at which clover is able to grow and give a yield of some consequence depends on a great many factors, but generally it is able to grow and give a considerable component yield (under suitable fertilization) up to 650 or 700 m. In the central Valdres area, and occasionally the border localities, growth may persist up to 800 m, but the winter can also be too hard and too long up the valley or mountainslopes. On the mountain station, Berset, situated at 1 000 m, we have experienced that seeded clover may survive the winter some times, but this is not to be generally expected.

SOME METEOROLOGICAL DATA

In the hilly and mountainous localities, the rainfall tends to rise with rising altitude. At Berset from the middle of June to the middle of August during a ten-year period, 44 mm more precipitation was measured compared with Loken (at 550 m). Totals for the same period were 189 mm at Berset and 145 at Loken. On upper hill land and in the mountains the moisture, as a rule, is adequate. But down in the valley it is more variable and many times inadequate.

Another component factor, the temperature, which in many cases is the limiting factor, is too low. Many times at Berset I observed damage to fescue and timothy after one or more nights of temperature near or under zero. However, the growth was quick and healthy again when the temperature went upwards for a week or two. The situation at and between the mountains reminded me of Troms county, nearly the utmost north of our country, where plants stimulated by 24 hours of daylength could grow very rapidly indeed, if only the temperature were high enough and permanent enough.

The difference in temperature between Berset and Loken for the months June–August is, in a ten-year period, 3.2 degrees Celsius. For the same months the temperature at Loken is observed to be 13.3 degrees and at Berset 10.1. This may be estimated as normal, and gives us 0.7 degree temperature fall for every 100 m elevation in the mountains. Our observations on this point are pretty well in agreement with the standard factor used by foresters, but our observations seem to be suggestive of bigger differences in May–June and lesser ones in the autumn.

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58.
Crop Diversification in Lowland Bolivian Hills

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On three different occasions, at different times of the year, I have been fortunate enough to explore a very peculiar, almost eerie, hill ecosystem, one I will call the coca hills of Bolivia (c2, 16° S, 67–68° W). Perhaps a remnant of an ancient Inca system, these frost-free hills of Los Yungas of Bolivia support very intricately terraced "cocales," i.e., planiations of the plant known in Spanish and now in English as coca, *Erythroxylum coca*, the source of cocaine.

I was there to consider the possibilities of alternative crops for coca. Apparently coca chewing is decreasing in Bolivia and Peru while coca production is increasing.

Not tolerant of frost, coca occurs in at least five life zones in Bolivia: the Tropical Wet, Tropical Moist, Tropical Dry, Subtropical Moist, and Warm Temperate Moist Forest Life Zones (without frost). According to Duke *et al.* (1975) coca is reported from areas with pH 4.3 to 8.0 soil, annual rainfall of 700 to 4000 m, and annual temperature of 17 to 27 C. It ranges from 200 to 2000 m elevation in Bolivia and can be grown at higher and lower elevations if heat and frost are not lethal. It flowers well as far north as Beltsville (in greenhouses), hence problems with daylight length are not readily apparent.

Cochrane (1973) suggests that coca grows from 20 N to 25 S and from 1000 to 2300 m, preferring high precipitation and temperature of 15 C or more. Strong dry winds are undesirable. Coca tolerates a wide variety of soils, but is sensitive to poor drainage. Unlike tea, coca does not need an evenly distributed rainfall nor exact soil conditions. There are hints that sulfur and magnesium may be limiting factors in some ex-coca Coroico soils.

Although larger coca plants are being produced in the tropical lowlands, the coca produced from the smaller bushes of the Yungas Hills is preferred by the *coquero*, or coca chewer, and the *contrabandista* or coca traffiker. Recent analyses performed by Dr. Norman Farnsworth, University of Illinois, suggest that hill coca contains more cocaine (dry weight basis) than lowland coca. Although the lowlands may produce more coca leaf per ha, available data suggest that coca from the classical terraced hills is higher in cocaine, hence more desirable for those who want a lot of alkaloid in a little leaf.

Emphasizing crop diversification potential for the coca hill ecosystem, I wish to indicate some problems of the upland as compared to the lowland *cocales* that make crop diversification proposals more difficult.

Gaskins *et al.* (1974) suggest several reasons:

a. Less water in Yungas
b. Rougher topography in Yungas
c. Poorer soils in Yungas
d. Poorer communication via road, river, or air with the exterior from Yungas
e. Poorer reception from the long-entrenched Yungas farmers.

For the hill *cocales*, the team, after reviewing a list of more than 500 species that can grow in coca life zones, refined the list using cultural, ecological, and economic criteria to five woody species groups: (a) citrus, (b) coffee, (c) quinine, (d) grapes, (e) macadamia nuts, and four herbaceous intercrops: (a) strawberry, (b) off-season vegetables, (c) tomatoes and (d) tobacco.

The purpose of this paper is to enumerate other crop species which combine certain attributes which make them viable candidates for crop diversification programs in the Yungas *cocales*.

METHODS

The Plant Taxonomy Laboratory has developed a Crop Diversification Matrix. Details of the matrix technique are published elsewhere (Duke and Terrell, 1974; Duke *et al.*, 1975). The 1000 species in the matrix have been scored for various cultural, ecological, and economic factors largely from the classical literature and from abstracted documents for 1970–1976. The National Agricultural Library at Beltsville alerts our Laboratory to new documents on the 1000 species. We have paid more attention to unusual than to usual species and have the data stored in manual and computerized information systems. These retrieval systems quickly tell us which of the 1000 crops are reported to contain any given combinations of characters.

RESULTS

Hill Species

Most plants, except certain aquatic and paludal species can be grown on hills. Many cases in the

literature suggest that hills are favored over flatlands for several species. A few of these are mentioned for the benefit of symposium participants. Most of this information is taken from our Crop Diversification Files and *The Wealth of India* (CSIR, 1948-69), a very useful third world source.

Of *Corylus avellana* L.: "It is common in gardens on hill stations. Attempts to raise plants in the plains have proved unsuccessful" (CSIR, 1948-69). Tumeric (*Curcuma domestica*) cultivated in the hills is reported to be of better quality than that raised on the plains. Good air circulation around quince (*Cydonia oblonga*), such as provided on slopes, is desirable.

Lemongrasses (*Cymbopogon* spp.) produce more oil on well-drained slopes than in wet bottomlands, where more foliage with lower oil content is produced. Citronella (*Cymbopogon nardus*) thrives on poor soil, especially on slopes or hills.

Artichoke suckers (*Cynara scolymus*) for planting on the plains are obtained from the hill gardens, where established plants may be cropped for 3 or 4 years. In the plains, the plants rarely survive beyond the first crop. *Cyphomandra betacea* (tree-tomato) is more often planted in hill regions, the growth being poor and sometimes fruitless in tropical lowlands.

In India, *Eucalyptus* is divided into species acceptable for (1) the plains, (2) the hills, or (3) both of these. *Feijoa* does better in hill stations than on plains stations.

Even in the U.S., slope may be recommended for strawberries (*Fragaria* spp.). Select a site that slopes to the south if you want an early crop, to the north for a late crop. On the negative side, sunflower (*Helianthus annuus*) is said not to survive well on steep slopes, though I have seen it intercropped with other species on gentle slopes in Iran as well as in my backyard. Jerusalem artichokes (*Helianthus tuberosus*) and sunchokes (*H. annuus X tuberosus*), although perhaps originally derived from alluvial species, are said to do better on slopes. Like olives, artichokes do poorly in mid-latitudes where photoperiod varies but little. In India, most *Hevea* plantations have been established on slopes up to 350 m.

Broad-leaved lavender (*Lavandula latifolia*) flourishes best on a warm slope with a south to southwest exposure. *Limnanthes alba* does best at 6.2 pH, especially on slopes. *Litchi* does better in the hills but the lower temperature may be more important than the slope.

Apple orchards (*Malus*) should be so situated as to allow cold air to settle below. On tops of ridges, wind may damage apples. *Morinda* thrives on sloping ground. Even a watercress (*Nasturtium officinale*) bed should have sufficient slope to allow good flow of water. Olives (*Olea europaea*) do best on Mediterranean slopes (but since they are said not to flower at latitudes below 25°, they are not to be recommended for Bolivia, unless new strains have been developed).

North slopes in dense shade are recommended for American and oriental ginseng (*Panax* spp.). Parsnips (*Pastinaca sativa*) thrive in a cool climate, and in India, hills are best suited. Kikuyu (*Pennisetum clandestinum*) is considered to be particularly suitable for moist hilly situations in India, where it is good for soil binding. The scarlet runner been, *Phaseolus coccineus*, is difficult to cultivate satisfactorily in most parts of India. It thrives with little care on the hills. Bay, *Pimenta racemosa*, grows in heavy clay on hilly slopes with 60 percent or more gradient, too steep for growing other crops.

In the northern hemisphere, such plants as black pepper (*Piper nigrum*), like ginseng, are preferably located on northern slopes to avoid intensive sun. Peas (*Pisum sativum*) are grown as a cool season crop or hill country crop in the tropics.

Plum (*Prunus domestica*) is best suited to hilly areas (850 to 1 450 m) in India, at least. Peach (*Prunus persica*) types of high quality and exquisite taste thrive well in mild hill areas. Sweet cherry (*Prunus avium*), peach and pear (*Pyrus communis*) should be located on slopes above the cold-air drainage pockets. Most pome and stone fruits of the temperate zone do better on slopes than on flat terrain.

Sandalwood, *Pterocarpus santalinus*, unlike the swamp *Pterocarpus*, requires perfect drainage and grows typically on dry hilly ground, sometimes on precipitous hillsides. Best areas for *Rauwolfia* combine high rainfall with proper soil drainage, such as slight slopes. Where winters are severe, raspberries (*Rubus* spp.) planted on hillsides are in less danger of winter injury, or late spring frost, than those planted in valleys. In southern areas of the northern hemisphere, sites with a northern or northeastern exposure are better in that they retain moisture and humus. Most if not all temperate berry crops fare better on slopes than on flat terrain.

The lulo, *Solanum quitoensis*, thrives on well-drained slopes of humid tropical and subtropical valleys. Chocolate species (*Theobroma*), like coffee species (*Coffea*), may thrive better on shaded hills. Slopes are preferred to flat ground for *Theobroma bicolor*. Being intolerant to wind, *T. cacao* often is planted on hillsides for wind protection and better drainage. With highbush blueberry (*Vaccinium corymbosum*), air drainage is important. Hence, slopes are recommended. For grapes, like *Vitis labrusca*, areas on hillsides around large lakes are considered ideal.

By now, you may correctly suspect that there may be more crops tolerant than intolerant of hill situations. Hence, the criterion hill tolerance does not

eliminate many candidates from consideration as alternative crops for coca in the Bolivian hills.

Longevity

In steep slopes, the intense cultivation of annuals, except as carefully nursed intercrops, is liable to induce erosion. Therefore, I suggest that we should consider only perennials, like coca itself, as major crops for the hill *cocales*. There are more perennials than annuals in our Crop Diversification Matrix, so the perennial criterion eliminates few candidates.

Life Zone Adaptability

Rainfall in Los Yungas (based on data from Coroico, Chulumani, Irupana, and Los Anguia) ranges from about 900–1 500 mm, averaging closer to 1 200 mm. The mean annual temperature at coca-growing levels ranges from about 18 to 21 C, averaging closer to 19 C. This suggests that much of the coca is grown in the Subtropical Moist Forest Life Zone, defined roughly (Holdridge, 1947) as the zone with the annual temperatures between 18 and 24 C, and annual precipitation between 1 000 and 2 000 mm rainfall. More species seem to tolerate the Subtropical Moist Forest Life Zone, eliminating few candidates.

Exotic to Yungas

Yields for Yungas could be improved with better germplasm of extant crops. However, I exclude from the Crop Diversification concept crops that are already grown in Yungas. The team observed or heard reliable reports of the following species being grown in Los Yungas (Table 1).

High Calcium–High Iron

If food were our main objective in an alternative crop for coca, we should select foods, like coca, high in iron and calcium. No plant in the Food Composition Table for Latin America (Wu Leung and Florer, 1961) is as high in calcium on an as-purchased basis as is coca.

The following items, some not usually consumed as food, are high-calcium, high-iron: *Areca catechu, Brosimum alicastrum, Camellia sinensis, Ceratotheca sesamoides, Chenopodium ambrosioides, Cicer arietinum, Corchorus olitorius, Cucurbita maxima, Cuminum cyminum, Eleusine coracana, Erythroxylum coca, Glycine max, Leucaena latisiliqua, Murraya koenigii, Perilla frutescens, Phaseolus vulgaris, Pimpinella anisum, Sesamum indicum, Sinapis alba, Solanum nigrum, Terminalia catappa,* and *Vigna unguiculata*. One part or another of the species is high in calcium and the same or another part is high in iron. These (except for *Areca*, another "narcotic") might be considered to supplement the diets of coca chewers who give up their coca, with its high iron and calcium content (Duke *et al.*, 1975).

TABLE 1. Crops cultivated in Los Yungas

Yields of some Bolivian crops are presented below. These data are presented to suggest with which native crops a new introduction might need compete.

Agapanthus sp.	Hydrangea sp.
Allium cepa L.	Ipomoea batatas (L.) Lam.
Ananas comosus (L.) Merr.	Juglans sp.
Annona cherimola Mill.	Lablab purpureus (L.) Sweet
Arachis hypogaea L.	Lactuca sativa L.
Arracacia xanthorrhiza Bancroft	Lens culinaris Medik.
	Linum usitatissimum L.
Asparagus officinalis L.	Luffa sp.
Basella alba L.	Lycopersicon esculentum Mill.
Beta vulgaris L.	
Beta vulgaris var. cicla L.	
Bixa orellana L.	Mangifera indica L.
Brassica sp. (cabbage, cauliflower, kale)	Manihot esculenta Crantz
	Medicago sp.
Calathea allouia (Aubl.) Lindl.	Musa paradisiaca L.
Canna edulis Ker	Nicotiana tabacum L.
Capsicum spp.	Opuntia sp.
Carica papaya L.	
Chrysanthemum sp.	Passiflora spp.
Cicer arietinum L.	Persea americana Mill.
Cinchona sp.	Petroselinum crispum (Mill.) Nym. ex A. W. Hill
Citrus spp. (orange, tangerine, grapefruit, lime)	
Coffea arabica L.	Phaseolus lunatus L.
Colocasia esculenta (L.) Schott (and Xanthosoma sp.)	Phaseolus vulgaris L.
Crotalaria sp.	Pimpinella anisum L.
Cucurbita spp.	Pisum sativum L.
Cucumis sativus L.	Polianthes tuberosa L.
Cymbopogon sp.	Raphanus sativus L.
Cynara scolymus L.	Rubus spp.
Cyphomandra betacea (Cav.) Sendt.	Solanum tuberosum L.
	Sorghum bicolor (L.) Moench.
Daucus carota L.	
Eriobotrya sp.	Spinacia oleracea L.
Erythroxylum coca Lam.	Tephrosia sp.
Eugenia jambos L.	
Fortunella sp.	Tetragonia expansa Murr.
	Vigna radiata (L.) Wilczek
Fragaria spp.	Xylopia aethiopica (Dunal) A. Rich.
Glycine max (L.) Merr.	
Gossypium sp.	Zea mays L.
Hedysarum coronarium L.	

Economic Considerations

According to Bolivian agricultural import statistics available to the team, the items in Table 3 are imported into land-locked Bolivia.

Many of these imports could be satisfied by crops that could be raised and produced in Los Yungas with appropriate infrastructure. Good wheat varieties for this life zone are not yet available in Bolivia (or elsewhere?), and the slopes are such that mechanized cultivation of any cereal should be discouraged. At the lower elevations where coca grows,

TABLE 2. Some Bolivian crop yields

(Based on unpublished files available at the Bolivian Ministry of Agriculture)

Crop	Yield Kg/ha
apple	5 300
banana	23 500
barley	700
bean (dry)	400
cabbage	1 500[a] (4 500)[b]
carrot	8 000
cassava	13 300
cherry	1 500
chocolate	600
citrus	12 000
coca	250
coffee	850
corn	1 250[a] (300)[b]
cotton	1 000
faba bean	850
garbanzos	500
garlic	2 500
grape	6 700
grapefruit	21 450-24 320[a]
kumquat	5 460[a]
lemon	900-9 400[a]
lime	4 500-21 930[a]
oat	675
oca	3 000
onion	7 000
orange	16 700[b]; 1 910-13 620[a]
peach	4 000
pear	5 000
peanut	1 100
pea	700[a] (3 000)[b]
plantain	16 000
potato	7 000
quinoa	750
rice	2 000
soybean	700[a] (6 000)[b]
strawberry	17 500
stringbean	10 000[b]
sugar	40 000
sunflower	800-1 440
sweet potato	7 500
tangerine	14 100[b]; 8 670-20 240[a]
tomato	10 200
ulluco	1 900
wheat	375

[a]Chipiriri
[b]Yungas

TABLE 3. Itemization of some 1971 imports to Bolivia

Product	Kilos	U.S. Value ($)
Honey	7 113	3,431
Olive	12 285	977
Patata[1]	9 595	926
Onion	91 557	14,680
Tomato	176 304	12,445
Zapallo[1]	55 022	2,135
Frijol	1 628	198
Dehyd. vegetable	13 275	10,062
Garbanzo[1]	130	95
Haba[1]	465	81
Lentil	41 251	12,378
Aji seco[1]	37 669	7,102
Sweet potato	415	239
Unshelled nut	170	36
Shelled nut	16	69
Date with pit	2 111	1,743
Date without pit	307	258
Grated coconut etc.	24 498	12,655
Dried Fig	143	149
Grape	122 854	17,606
Raisin	28 495	19,306
Apple	3 726 936	643,921
Pear	9 141	1,406
Apricot (plus peach)	1 351	306
Cereza[1]	305	39
Ciruela[1]	225	22
Watermelon	1 060	317
Ground coffee	44	353
Tea	303 596	341,506
Paraguay tea	171 217	38,944
Pepper (Piper)	77 041	75,969
Ground pepper	1 680	2,270
Vanilla	225	37
Canela (cinnamon)	77 832	104,107
Ground cinnamon	5 763	7,802
Clove (clavo)	7 757	32,500
Nutmeg (whole)	3 336	4,415
Nutmeg (ground)	187	587
Anis, seeds of badiama, hinojo, cilantro, comino, alcasara y enebro[1]		
Comino (whole)	167 419	122,420
Comino (ground)	36	124
Anis + badiana (Anis estrellad)	341	366
Tomillo,[1] laurel,[1] azafran[1]		
Not ground	639	1,109
Ground	252	736

(Continued)

TABLE 3. (Continued)

Product	Kilos	U.S. Value ($)
Cereals		
Wheat	44 105 635	3,896,330
Barley	12	23
Oats	273 093	45,152
Corn	5 462	1,868
Rice	30	30
Other cereals	2 974	969
Cereal total	48 309 990	4,962,130
Lupulo (Hop)	98 091	125,220
Carrofas (ceratonia)	77	223
Gums and resin	38 569	24,585
Pork lard	17 733 608	5,832,407
Chicken fat	10 812	3,394
Pork fat	66 140	55,854
Fish liver oil	8 768	3,471
Linseed oil	19 938	7,784
Sunflower oil	345 931	142,114
Olive oil	130 602	56,026
Refined vegetable oil	3 234 562	1,013,639
Crude vegetable oil	2 216 221	826,311
Linseed	± 125 000	± 45,000
TOTAL OILS AND FATS	26 285 711	8,562,928
Other small categories		
Glucose	41 305	6,097
Chewing gum	124 824	160,097
Candies, etc.	70 032	74,038
Total confectionery	255 802	252,493
Chocolate and products	81 430	104,511
Flour and noodles	1 357 205	437,250
Liquers and vinegar	562 897	225,817
Diverse prepared food	297 333	487,637
Tobacco products	466 619	805,117
Fertilizer	4 917 417	584,536
Paper	6 414 880	1,830,186
Flax and ramie	1 305	2,427
Cotton and its products	183 795	530,866
Peanut butter	489	662
Ketchup	39 634	24,765
WHOLE TOTAL	161 235 491	34,758,867

[1]Not translated because the name can have different botanical meanings in different Latin countries.

the chill factor requirements of most varieties of apples and other pome and stone fruits could not be satisfied. The literature suggests that olives will not flower at low latitudes. Cloves might require a more humid tropical environment, as might black pepper. Flax was observed as a weed in one coca field, hinting that linseed oil, though not recommended as an alternative, could be produced in hill *cocales*. Although different species might be involved, cereals, oilseeds, fruits, teas, liqueurs, and spices imported into Bolivia could be produced in Yungas, but perennial tree sources are to be recommended instead of annuals.

More important, coca, like opium and even marihuana, is a crop with a high-priced, labor-intensive, low-weight end product. The more remote the Bolivian coca field, the more important it is that proposed replacements have such attributes. Several species share these economic attributes, but many of them may do better in ecological situations other than the Bolivian hill *cocales*.

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59.
Appraising Land Potentials for Commercial Apple Production*

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Interest in appraising the suitability of land for apple production has increased in recent years due to the high rate of returns which can be obtained from relatively small orchards.

Several features associated with suitable orchard sites are found in hill lands: fields, often limited in size and shape, are suited to high intensity agriculture; land is available for orchards since many hill areas are used for such non-cultivated production as pasture, hay, and timber; and since apple production is labor intensive, it is well suited to the small family farm. However, orchards require sizeable investments, and proper site selection will directly influence the feasibility of apple production (Gardner *et al.*, 1922).

This study attempts to describe what constitutes a favorable apple orchard site. In doing this it was necessary to learn why some apple producing areas have developed, why some have failed, and why still others in seemingly less favorable areas have persisted.

BACKGROUND

Relative to general agriculture, apple orchards, as a monocultural system, are young. Prior to the 1870's most apples were grown on general farms, along with other garden crops, and sold locally. These apple trees were grown from seed and consequently the apples were extremely heterozygous.

In the late 1800's as cities expanded and agriculture became more specialized, the farm orchard plots were increased in size to produce fruit for the expanding urban populations. Orchards often were relegated to hillsides and other sites not suited for extensive farming. Marketing apples in distant cities required development of orchards which could produce quantities of standardized fruit. Consequently, standardization meant fewer varieties having consistently better quality and yield were grown. Also mixed plantings of seedling trees were replaced by plantings of a few varieties propagated by grafting. This trend resulted in increased pest problems, making pesticides and improved control measures essential. Furthermore, as production costs increased, better orchard management was required.

In a period of 50 years, apple orchards became viable enterprises. Unfortunately, millions of dollars were lost as entrepreneurs and unexperienced growers planted thousands of acres in unsuitable locations as in Dufur, Oregon, and western Colorado (Ure and Binkley, 1976). A study of the development and decline or continuance of apple production areas provides insight into the selection of favorable orchard sites. Folger and Thompson (1921), Maynard (1923), Rees (1926), Upshall (1976), and the Washington State University Library Archives provide much historical background used in this study.

MATERIALS AND METHODS

The problem of determining a system of appraising land potentials was approached in three different ways: (1) a literature search to determine the factors limiting the growth and development of fruiting apple trees and to evaluate various studies which have been utilized in orchard site selection; (2) crop and acreage statistics to identify major worldwide apple producing areas and changes which have taken place; (3) literature and on-the-site analysis of the changes which have taken place in local fruit-growing areas in Washington.

In this approach, particular attention was given to the literature, statistics, and the historical resumes of apple producing areas of the United States, since this information was most readily available. It was gathered from industry, commodity groups, and horticultural organizations, the U.S. Census, the U.S. Statistical and Crop Reporting Service, State Land-Grant Universities, and the USDA.

In the major apple producing regions of the world, production is centered in hilly or mountainous areas, along river valleys and near large bodies of water. Textbook descriptions of apple orchards, such as those found in Gardner *et al.* (1922), Chandler (1925), and Childers (1969), state that the selection of a favorable orchard site is a major factor in its profitability. Kramer and Kozlowski (1969) grouped those factors important to favorable sites in three categories: edaphic, climatic, and biotic. Other factors not mentioned by them but equally important are those related to management, marketing, and commerce. Many of the factors can be compensated for by horticultural practices in moderately unfavorable conditions. For example, irrigation can supplement low natural precipitation.

*Based on M.S. thesis, Washington State University, 1976.

Pruning can increase light intensity and spray penetration into the tree as well as regulate cropping. Orchard heaters and other frost control devices can reduce frost hazards. Fertilizers can compensate low soil fertility. Marketable cultivars grafted on locally adapted rootstocks enable production in colder climates and in unfavorable soil conditions and provide control of tree growth and fruiting. All these are examples of horticultural practices designed to minimize environmental factors.

EDAPHIC FACTORS

The edaphic factors common to favorable sites are related to soil, topography, and land.

The soil provides anchorage, nutrients, and water, all of which are essential. Apple trees can be grown on a wide range of soil textures and types, but infertile soils, highly variable soils, poorly drained soils, shallow soils, or soils with toxic substances will result in significant management problems (Chandler, 1942). However, deep fertile soils can minimize the effects of some less favorable aspects of the physical environment.

For example, deep volcanic soils with high water-holding capacity have enabled the non-irrigated production of apples in the White Salmon River area of Washington. The summer rainfall deficiency in this area is offset by retention of winter precipitation in the deep soil.

LAND

The availability of land and competing land uses significantly influences orchard site location. In marginal apple orchard locations, more profitable alternative crops will be grown if environmental conditions are favorable. The possibility of producing an alternative crop accounts for some orchards going out of production, while others have no option but to continue raising apples (Krueger, 1963). For example, more profitable row crop farms replaced many orchards in southern Idaho and many Midwest states (Horn, 1976).

Another alternative land use is urban development, which is a constant threat to orchards located close to consumers. Urban development is more likely to absorb the smaller, more marginal orchards instead of large orchards. The lack of alternative land use is one reason why apples will be grown in seemingly less favorable locations and conditions.

Orchards often occupy specific sites and are frequently associated with other agricultural endeavors. The common location is on a hillside or sloping ridge above pastures or cultivated lowlands (Kimball and Gilbert, 1967). Upland sites, being less suited for cultivated crops and land development, become prospective orchard sites. Orchard slopes should be at least 3% to provide air and water drainage. However, orchards have terrain limitations resulting from modern mechanization and labor preferences and topography limits field size and orchard operations (Childers, 1969). Slopes greater than 20%, unless terraced, are difficult and hazardous for farm machinery operation (R. B. Tukey, 1971). Orchards must be large enough to provide the grower with sufficient income while providing for necessary replant area.

CLIMATE

Climate has a major influence on growth and fruiting potential of a tree. Included are light intensity, quality, and duration; seasonal and diurnal temperatures; amount, form, and distribution of precipitation; and wind and air movement. Extremely cloudy locations can cause reduced photosynthesis, increased susceptibility to fungal diseases, and reduced yield and grade. However, cloudy nights are an advantage in spring frost prevention since the earth's heat, given off at night, is trapped below the clouds. A greater importance seems to be the light intensity within the tree canopy itself. Studies by Heinicke and Hoffman (1933) indicate that light intensity within the canopy limits fruit color when it falls below two-thirds of full light and limits fruit production when it falls below 40% of full light.

Temperature

Temperature is probably the most limiting climatic factor in apple production (Blampied and O'Kennedy, 1967), (Kramer and Kozlowski, 1960), (Childers, 1969). It is influenced by altitude, wind, humidity, light intensity, slope, ground cover, tree spacing, and proximity to large bodies of water (Hogg, 1970). Apple trees require sufficient cold during the winter to fulfill dormancy, thus enabling flower development. Most marketable apple cultivars require at least 1000 hours at temperatures below 7.2 C (Magness and Traub, 1941). This chilling requirement has limited production in warmer parts of the world since failure for a tree to fulfill dormancy results in erractic bearing and reduced yields (Kramer and Kozlowski, 1960). However, extremely low temperatures are often credited with the elimination of entire apple production districts, such as Kansas, Illinois, Iowa, and portions of New England (Folger and Thompson, 1921). Furthermore, certain varieties such as Baldwin and Rhode Island Greening dropped out of production due to severe and widespread winter freezes.

Spring frost is a major hazard since it can kill the young bud. A growing season of at least 135 days, and preferably 160 days, is needed for most marketable cultivars (R. B. Tukey, 1971). During the growing season, temperatures between 0 and 35 C are preferred. At temperatures greater than 35 C, respiration exceeds photosynthesis and fruit development ceases (Heinicke and Hoffman, 1933).

TABLE 1. Interaction of factors significantly affecting apple orchard location

soil salt, toxics, uniformity																										
X	*soil fertility*																									
·	·	*soil texture*																								
·	·	·	*light intensity*																							
·	·	·	*seasonal temperatures*																							
·	·	·	*daily temperatures*																							
·	o	o	*growing season*																							
·	·	·	1 *wind*																							
X	o	X	*precipitation effective*																							
X	o	X	X	·	X	o	o	o	X	*irrigation*																
·	·	o	·	·	o	o	o	X	o	o	*terrain—topography—slope*															
o	·	·	·	·	·	·	·	·	·	·	X	*orchard size*														
·	o	o	·	·	·	·	·	·	o	o	X	o	*competing land uses*													
·	·	·	·	·	·	·	·	·	·	·	·	X	X	*distance to major growing area or population center*												
·	·	·	·	·	·	·	·	·	·	·	o	X	·	X	*skilled labor*											
·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	·	*storage facilities and packing*										
·	·	·	·	·	·	·	·	·	·	·	o	·	·	X	·	o	*transportation facilities*									
·	o	·	·	·	·	·	·	·	·	·	·	X	·	X	·	·	o	*supplies and equipment*								
·	o	·	·	·	·	·	·	·	·	·	·	o	·	X	·	·	·	o	*technical assistance*							
·	·	·	·	·	·	·	·	·	·	·	·	X	o	o	o	o	o	o	X	*community support—loan*						
·	·	·	·	·	·	·	·	·	·	·	·	X	·	·	o	·	·	·	o	·	*political stability*					
·	·	·	·	·	·	·	·	·	·	·	·	X	·	o	·	X	X	·	·	·	X	*markets*				
X	o	o	o	·	X	o	X	X	o	o	·	·	·	·	o	X	o	·	o	·	X	varieties—plant material				
X	X	o	X	·	X	X	o	o	X	X	·	·	·	·	X	o	o	o	X	·	·	X	X	*fruit size, quality, consistency*		
·	·	·	·	·	o	o	o	o	X	o	·	X	·	o	o	o	·	X	X	·	·	·	X	X	*pests and pest control*	
X	o	X	·	·	·	·	o	X	X	o	X	X	·	X	X	X	X	X	X	X	o	X	o	X	X	*orchard operations*

X = Factor of high significance compensated with advanced skills and/or major capital investment.
o = Factor of moderate significance compensated with moderate degree of skill and/or capital investment.
· = Factor of low significance, a minimal skill and/or capital will compensate.
1 = Interaction not related to current study, little or no interaction.

Largely because of temperature effects, worldwide apple production is restricted to higher altitudes in lower latitudes and to lower altitudes in the higher latitudes (Chandler, 1925 and Kramer and Kozlowski, 1960). For example, apples are grown in the outer Himalayas of India at 1 525 to 2 745 m elevations and at 976 m elevations in the Lebanese Mountains of Lebanon (Rajput, 1969 and Kamper, 1965). The moderating effect of warm oceanic currents permits apple production in Norway, Finland, Sweden, Washington, and British Columbia. Conversely, the cool Benguela ocean current makes production possible in South Africa. Orchards are often located in hilly terrain because such terrain not only provides the necessary temperature modification, but at the same time, provides air drainage to reduce frost hazards.

Wind

Wind and its effects substantially and often negatively influence tree growth, fruit quality and yield, and orchard operations. Although some wind is desired on frosty nights to prevent air stagnation and bud freeze, excessive winds damage the tree and fruit (H. B. Tukey, 1974). Wind effects are related to the frequency, duration, and occurrence of wind, as well as the speed of the average winds and gusts. In many instances, orchard wind speeds can be reduced by planting wind breaks, but these are successful only for a limited distance from the wind breaks (Van Rhee, 1957).

Since hill lands generally are associated with winds, wind effects need greater consideration in site selection (Wang, 1972 and Gloyne, 1967). High winds accompanied with low temperatures will increase winter injury, while high summer winds in association with high temperatures and low relative humidity will dessicate a tree, reducing fruit growth. During the growing season young unsheltered trees exposed to persistent winds result in fruit bruising and tree flagging (branches bending in the direction of the prevailing wind). Tree bearing surface, and consequently yields, will be greatly reduced by this bending. In windy parts of England, the Netherlands, Argentina and South Africa, tall wind breaks are considered essential for apple production (Van Rhee, 1957). Aside from the effects on tree growth and development, wind may interrupt or reduce the effectiveness of such orchard operations as sprinkler irrigation and spray application.

TABLE 2. Description of a prime apple orchard site in Washington

Soil depth	Greater than 76 cm without any impervious layers
Soil texture	Sandy loam
Effective precipitation	At least 100 cm distributed throughout the growing season, or irrigation water available when needed in amounts needed
Sunlight	Cloudy winters and springs, cloudless growing season
Average wind velocities	Not over 7 kph
Winter temperatures	1 000 hours with temperatures less than 7.2° C, no temperatures below −20° C
Frost-free period	165 days, no frost following 1 000 degree days (mean daily temperatures less than 6° C) beginning Feb. 1 until harvest
Summer temperatures	Days approximately 21° C, nights approximately 10°–18° C
Orchard size	16 ha total with individual fields of 4 ha
Land slope	3 to 5%
Availability of land	No significant competition from other land or agricultural use
Pests	Readily controlled with available labor, equipment, and technology
Fruit cropping	Consistent yields of marketable quality
Varieties	Marketable and world varieties grow normally
Marketing	Reliable local markets and/or organized long distant markets
Community support	Growers in sufficient numbers and size to be recognized as a viable enterprise in the community
Equipment, supplies and skilled labor	Available within commuting distance
Technical assistance	Frequent consultation, at least weekly
Storage and transportation facilities	Readily accessible

Precipitation

Tree growth and fruiting are dependent on adequate soil moisture since photosynthesis can occur only when the tree has sufficient moisture. Therefore, precipitation or irrigation are needed during the growing season to maintain proper soil moisture. Optimal precipitation is related to several variables, including the evapotranspiration rate, relative humidity, air temperatures, light intensity, wind, soil water-holding capacity, and the cultivar (Chandler, 1942). Apples are successfully grown in England despite low annual precipitation because of uniform distribution throughout the growing season and low evapotranspiration rate. Not all precipitation is welcomed however. Some comes in the form of hail which can destroy both crop and trees in minutes (Childers, 1969). Also, snow can reflect the bright winter sun onto a tree trunk and cause internal temperature gradients that will shatter wood and kill the tree. Conversely, snow cover can insulate cold-sensitive roots and permit apple production in areas of low winter temperatures (Gardner *et al.*, 1927). Snow also aides in soil moisture retention by enabling melt water to penetrate the unfrozen ground. Often not considered in classification schemes is the effect of precipitation, including snow on orchard operations such as pruning, spraying, and harvesting.

MICROCLIMATE

The spacing and orientation of trees in the orchard, the presence and type of ground cover, and growth and fruiting habits of different cultivars combine to form a microclimate within the orchard (Landsberg, 1972). This can influence orchard operations, the incidence of pests and diseases, fruit set, yield, and fruit quality. For example, rows planted perpendicular to slope will retard air drainage, especially when dwarfing rootstocks are used (H. B. Tukey, 1964). Poor air drainage increases frost hazards (Chandler, 1925). Row orientation will influence light intensity and penetration in the canopy (Cain, 1972). Most ground cover insulates the soil, preventing loss of soil moisture and heat. The cooling effect of ground cover tends to retard flowering in the spring and reduces frost hazard.

BIOTIC FACTORS

Most biotic factors of the environment can be readily controlled by modern pesticides and other pest control techniques which have generally minimized the effects of most orchard insect pests, diseases and weeds. But frequent and severe outbreaks of diseases and insect pests reduce the economic stability of an apple industry. For example, failure to develop adequate coddling moth control measures led to the decline of the apple industry in the Ozarks (Folger and Thompson, 1923). Another biotic factor is man whose activities may adversely affect apple production, due, for example, to urban encroachment, air pollution and adjacent neglected orchards which harbor insect and disease pests. Furthermore, extensive orchard plantings will often result in population shifts in the natural biota and growers must devise methods that will compensate.

For example, wildlife such as deer, mice, gophers, rabbits, and birds may be serious pests in isolated areas where other, more common orchard pests are not prevalent.

COMMERCE

A group of factors commonly overlooked are those related to commerce. Their influence on orchard site suitability is difficult to assess. In selecting an orchard site, consideration should be given to the availability of skilled labor and technical assistance, the availability of supplies and equipment, community support, political stability, storage and transportation facilities, and the availability of favorable markets. Modern orchards require that sufficient labor be available to engage in necessary orchard operations. Even experienced orchardists require technical assistance to repair equipment, to advise on technical problems such as soil fertilization and pest control, and to access numerous other ancillary services. Orchards require ready access to supplies and equipment such as fertilizers, pesticides, growth regulators, irrigation equipment, and farm machinery. Producing apples for the best return on the investment depends on adequate storage facilities in order to hold the apples until the market is favorable, and transportation facilities to get the fruit to market as needed and in good condition.

MARKETING

Orchards located near urban markets are considered to have a marketing advantage (Rees, 1921). Some growers, such as those in the Pacific Northwest, must sell apples to distant markets. Successful long-distance marketing developed as a result of standardization of grades, consistent yields, storage facilities, and transportation (Maynard, 1923). The advent of cold storage and transportation resulted in a major shift in acceptable varieties. For instance, the Baldwin, Ben Davis, and Winesap varieties were replaced by other, more suitable varieties. Areas unable to switch to more marketable varieties went out of production (Folger and Thompson, 1921).

The Bitteroot Valley apple district of Montana died out, not due to climatic adversity, but because of inadequate marketing (Metcalf *et al.*, 1976). Growers in Doniphan County, Kansas, have long been cited for their cooperation in keeping their district, the only significant one in the Midwest, alive (Folger and Thompson, 1921). Grower cooperation in Washington is largely credited with the growth of that state's apple industry (Maynard, 1923). New England growers also united in the 1920's to salvage their declining industry (French, 1976).

Grower cooperation has proved necessary to assure the nonphysiological factors affecting prime orchard sites. Failure to develop regional pest management had disastrous results in the Ozark apple growing region (Vaile, 1976), as well as in much of Maine's apple growing area (Folger and Thompson, 1921). Growers need to be concentrated enough to justify specialized technical assistance, supplies and equipment, and community support-loans. Only groups of growers can attract these factors of commerce. Growers serving local isolated markets fare well, but those isolated from markets and other growers generally fail. Isolated growers have to be exceptional orchardists, mechanics, and businessmen. They get little advice or service and must convince creditors of the worth of an unfamiliar business.

POLITICAL STABILITY

Apple production and marketing also are dependent upon political stability. For example, Argentina is sometimes unable to transport its fruit as a result of civil strife. Tasmania's apple industry was significantly shaken when its prime customer, England, joined the European Common Market. Even in the United States, government regulations, labor and finances, all subject to political influence, affect orchard site selection and operation.

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60.
Tree Fruit Production in the Mountains of the Central Atlantic States

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The Central Atlantic states of Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and West Virginia were responsible for 19% of the United States commercial apple crop in 1975 and 11% of the peach crop. The so-called Cumberland-Shenandoah region is roughly geographically contiguous across the several states, produces a unique combination of cultivars, and supplies a common group of markets. In some of these states, particularly Maryland and West Virginia, references are commonly made to "valley" and "mountain" orchards. In 1964, the last year for which the appropriate data seem to be available, 68% of the West Virginia apple crop was produced in the Shenandoah Valley counties of Jefferson and Berkeley and 24% in the mountain counties of Hampshire, Morgan, and Mineral. Although all these counties lie within a radius of 58 km, and within the same minutes of longitude (78–79 W) and latitude (39–40 N), there are considerable differences in soils, elevation, topography, and climate, some of which are shown in Table 1 (Lee *et al.*, 1973; Lee *et al.*, 1976).

No pretentions are made that these differences are overwhelming or that valley and mountain areas never overlap. Lee *et al.* (1969) found that the mean annual temperature decreased about 1.5° for each increase of 300 m of elevation at a given latitude in the Northeast, including West Virginia. Satisfactory climatological data for many points are not available. At Kearnysville, near the Berkeley-Jefferson border, there were 3199 growing degree days (50 F) in 1968 as compared to 2679 at Elkins, W. Va., which is used as a release point because it is the nearest record station. Although the elevation of Elkins (607 m) is considerably higher than Hampshire County's median elevation, it should be permissible to infer that Hampshire County is somewhat cooler than the lower valley. Martinsburg in Berkeley County (175 m) has a growing season of 177 days between killing frost while Romney in Hampshire County (194 m) has only a 144-day growing season

TABLE 1. Some geographical and topological characteristics of West Virginia's principal tree fruit producing counties

County	Median Elevation (m)	Total Relief (m) (Maximum minus minimum)	Mean Slope Inclination (%)
Berkeley	173.7	582.1	11.3
Jefferson	158.5	451.1	7.2
Hampshire	360.3	869.2	16.7
Mineral	312.7	824.4	19.0
Morgan	249.9	591.3	20.6

(USDA, 1941). Over a 38-year span of record keeping ending in 1941, Romney had about 100 mm less annual precipitation than Martinsburg, but essentially the same distribution.

Soils can also be used to distinguish the valley and mountain orchards. Essentially all the orchards in Berkeley and Jefferson and adjacent counties of Virginia and Pennsylvania are planted on Frankstown (Typic Hapludult), Duffield (Ultic Hapludalf), Frederick (Typic Paleudulf) soils, which are deep, medium-textured soils derived mainly from limestone and underlain by limey shale and limestone (Gorman *et al.*, 1966, Hatfield *et al.*, 1973). Outcrops are prominent in many valley orchards and necessitate some extra care in planting and operation of vehicles, but for the most part cultivation is relatively easy. Most of the mountain orchards are on soils of the Berks (Typic Dystrochrept), Weikert (Lithic Dystrochrept), Lehew (Typic Dystrochrept), Dekalb (Typic Dystrochrept), Associations (Typic and Lithic Dystrocrepts) which range from shallow to moderately deep and are always well drained. Mostly these are shaly-silty or cherty-silty soils derived from shale, siltstone, and sandstone. They are, therefore, a good deal more acid than the limestone-derived soils of the valley. A few mountaintop orchards are on soils characteristic of the valley and a few are on soils containing cherts, which are flinty inclusions remaining after limestone is dissolved. Mountain orchard soils give the overall impression of being shallow and coarse.

While many histories of the Middle Colonies mention tree fruits as common farm and garden crops, there are few details about cultivars or cultural methods. The Albermarle Pippin (Yellow Newtown) is often cited as one of the first, probably the first, apple cultivars to have originated in the New World as a seedling. Subsequently, a number of other varieties emerged from the Mid-Atlantic region and became important in other fruit producing regions of the United States: Golden Delicious, Grimes Golden (both of which were found in West Virginia), and Ben Davis are a few (Bailey, 1935). Originally writing about 1900, Bailey considered some of the best orchard sites as being strung out along lower slopes, particularly of the Blue Ridge Mountains of Virginia and North Carolina, where apple trees with a girth of three feet had been found. Such trees would date fruit growing back to the beginning of the nineteenth century at least. The authors have heard stories of orchard establishment by itinerant (and unsuccessful) tree peddlers after the Civil War.

According to accounts by a third generation grower, peaches were the first fruit crop grown commercially in the mountain counties of West Virginia, starting around 1900. This coincides with the introduction of longer-keeping cultivars such as the Carmen. Better transportation facilities also must have been a factor in the establishment of new commercial orchards. Peach yellows, a virus disease, first appeared in Morgan and Hampshire counties about 1910. As peach orchards died off, apples were planted as an alternate crop. Apples now predominate, although peaches have become important again after the introduction of cultivars less susceptible to yellows.

Why would anyone try to grow apples and peaches in the mountains? Cultural operations have been difficult because of the steep slopes. The thin soils obviously have poor nutrient and water-holding capacity. The parent material under the shallow soils impedes root penetration and prevents good plant anchorage. As expected, growth rates and ultimate tree size appear to be much less than in the nearby valleys. This conclusion is based mostly on observation rather than any sort of conventional experimental or quantitative data; however, Young (1966) provides some quantitative support. In 1965, 31% of the York apples from a Hampshire County orchard were less than 2 1/4" in diameter while only 3% from a Berkeley County orchard were that small. It is difficult to see how an experiment without countless variables could be devised to measure differences between the two growing conditions. Mature orchards in Jefferson and Berkeley counties commonly yield 12 MT/ha; 8 MT/ha would be an outstanding yield in the mountains.

Soil deficiencies in the mountains are at least partially compensated for by climatic conditions. The many mountain slopes make it fairly easy to find sites with good air drainage, where the danger of spring frosts, probably the greatest hazard to fruit production in the valley, is comparatively slight. In spite of rigorous site selection, crop losses exceeding 50% occur one in five years in Berkeley County. Grower records indicate that losses are much less frequent in the mountains (Weedfall *et al.*, 1967). Hail, always a hazard in the production of any crop, is reported less frequently in the mountains than in the valleys.

Temperature means are somewhat less in the mountains than in the valleys. The differences become more pronounced in August and September, at the end of fruit development. There is some evidence of an inverse relation between late-season temperatures and fruit-keeping quality. Growers in the mountains believe that their fruit keeps better than fruit from the valley and, in general, allow themselves a longer marketing season.

The quality of tree fruit, particularly apples, is largely defined by color. In the United States, red cultivar fresh market apples are graded Extra Fancy, Fancy, etc., on the basis of the fraction of the fruit surface colored with red. Light is required for formation of the red anthocyanin pigments. Color formation is greatest when light intensity and daytime

temperatures are high and nights are cool to slow the degradation of intermediates in anthocyanin synthesis. High available nitrogen seems to reduce fruit color by increasing leaf area and shading of fruit and perhaps competing for the substrates for anthocyanin production. It has always been the contention of fruit growers with orchards at the higher elevations that their fruit is better colored as well as better keeping. This is supposed to mean that a large proportion of the mountain-grown fruit can be sold on the fresh market while the poorly colored fruit produced at lower elevations must be sold for processing. Net returns for fruit sold on the fresh market generally exceed the return for processing fruit. Thus, the greater net return per ton is supposed to compensate for the lower tonnage produced in the mountains as compared to the valleys. To evaluate the accuracy of this contention it would be necessary to collect a great amount of pack-out data which shows the percentage of orchard run (total yield) fruit that meets grade specifications. It is not likely that such data is readily available or would be very consistent between operations. Furthermore, a few simple calculations would suggest that tremendous pack-out differences would be necessary to account for the 50% greater total yield differences that have been indicated.

The introduction of budsports or cultivars with much greater genetic potential for red color make it possible to produce high "quality" apples and peaches under a much wider range of nutritional and weather conditions. Some strains of Red Delicious and Rome Beauty apples grown in the warm humid valleys of Virginia, West Virginia, and New Jersey pack-out 80–90% of total yield. Further improved storage facilities and methods have reduced the influence of growing conditions and fruit condition at harvest on storage behavior.

For a considerable period of time, mountain orchard operators found labor more available. The mountain orchards were rather isolated and removed from population centers and competition from other industries. Many natives of the mountains and valleys seemed content to stay in place and accept the work available. These conditions seem to persist but the advantage, if indeed there is one, may be dwindling. As the labor supply has contracted in the valleys, mechanization has increased. The large air-blast sprayers that used a team of two men rather than five were easy to use on slopes of 0–5%; much modification and loss of efficiency were required to use the same machines when the slope increased to 10–12%. Concentrate sprayers, which apply pesticides in 30–60 gallons of water per acre rather than the traditional 300–500 gallons, require precise speed control which is difficult to obtain on steep slopes. The large pallet boxes or bulk bins holding 300–500 kg rather than 20 kg of the older "field box" reduced the labor required for hauling and increased picker efficiency 10–20%. Some hillside orchards still cannot use bulk bins effectively.

The continued existence of the hillside orchards presumably means that they are more profitable than other alternative uses of the resources used in these orchards. However, it seems fair to ask what would happen if the availability and adoption of new technology enabled valley orchards to improve efficiency to a greater extent than mountain orchards. If this situation occurred, it is doubtful that the mountain orchards could continue production in the long run. This unique and profitable orchard system for hillside utilization would fall to a new set of biological and economic forces.

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62.
No-Till Corn Production in Tall Fescue*

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Rolling hills and soils of the 18 million ha Southern Piedmont region, USA, are highly erosive when clean tilled. A mild climate and year-round distribution of 125 cm average annual rainfall permits growth of summer and winter crops when soils are properly limed and fertilized. There is a high probability of the occurrence of short droughts each year (van Bavel and Carreker, 1957) in the region, and crops have shown favorable response to irrigation (Carreker and Cobb, 1963). Carreker and Barnett (1963) and Hendrickson *et al.* (1963) showed the seriousness of runoff and soil loss in the Southern Piedmont. Adams and Barnett (1965) showed that both runoff and soil loss are negligible from grass sod, and low from row crops following a dense sod on moderate slopes. Although no-till planting in plant residue or viable sod to reduce water erosion has been recognized as a desirable goal, the development of modern herbicides makes this goal obtainable. However, a coordinated management of plant spacing, soil water, and fertility is needed to achieve good crop production.

Early efforts to develop tillage systems that completely eliminated plowing were not too successful. Faulkner (1943) advocated disking rather than plowing for soil preparation. Borst and Mederski (1957) developed a system of mulch tillage for production of row crops in which soil was stirred and weeds killed with a field cultivator, leaving much of the plant residue on the soil surface. Neither Faulkner's system nor mulch tillage were widely adopted in the humid East, USA. Development of modern herbicides reduced the need for frequent and complete stirring of the soil for weed control and made development of some newer conservation tillage methods possible. Some of the earliest work using herbicides as a substitute for tillage was pasture improvement in New Jersey (Sprague, 1952). At the time of these experiments, only a few chemicals were available to suppress unwanted vegetation. Davidson and Barrons (1954) produced crops without tillage in the early 1950's. Herbicides available at the time made the procedure laborious. During the mid-1950's work was done on reduced tillage for corn production by C. R. Skogley.[1] Corn was planted in a roto-tilled strip using a conventional planter. This research did not produce outstanding corn yields.

Timmons (1970) reported that 1959 was the first year for public use of atrazine. In 1959, Free *et al.* (1963) began work on "zero-tillage" for corn following sod. In 1960, Moody *et al.* (1961) grew corn without tillage in Virginia, as did Triplett *et al.* (1964) in Ohio. Results were encouraging in all three cases. In 1961 through 1963, Adams *et al.* (1970) grew no-till corn in live Coastal bermudagrass and fescue sods by stunting the sods with maleic hydrazide prior to corn planting. They obtained good corn and grass yields when irrigation was used. Blevins *et al.* (1971) observed during 1969 and 1970 in Kentucky that soil water content in a silt loam was higher throughout the growing season to a depth of 45 cm under no-till corn in killed sod than under corn with conventional planting on clean-tilled land, and that no-tillage systems generally produced higher corn yields with poor or favorable rainfall. D. M. van Doren *et al.* (1969) found that incomplete killing of crop cover increased competition with corn for moisture and decreased corn yields. The highest corn yields occurred where the highest amount of cover also occurred for soils with low structural stability. Herbicides have been used to stunt or make dormant fescue sod for corn grain production.[2]

Literature has been reviewed by Stanford *et al.* (1973) on plant nutrient behavior and requirements in relation to minimum- and no-tillage practices. They concluded that on direct evidence alone there is meager basis, particularly in the humid USA, for evaluating the problems of how recent and dramatic changes in tillage practices affect plant nutrient needs and behavior. Considering the broad range of no-tillage practices involving sod planting of corn,

*Mention of a commercial product does not imply endorsement by the USDA to the exclusion of other products which may be equally suitable.

[1] Seedbed Preparation for Corn After Sod, Ph.D. dissertation, Rutgers University, New Brunswick.

[2] J. M. Spain, G. C. Killingman, and C. K. Martin. 1966. Dormant Sod Planting. Progress Report, North Carolina State University, Raleigh. (These researchers were not able to get consistent grain yields in successive years because of their inability to control the degree of sod stunting. When stunting was incomplete, grain production was greatly reduced.)

they concluded that it appears that the relative cumulative effects on organic N content of soils over time cannot be generalized. Davies and Cannell (1975) reported from studies in the UK that the response of no-tillage crops to N fertilizer sometimes differs from that of conventionally cultivated crops. They reported that in 45 experiment years with winter wheat the N levels giving the highest yields for no-tillage crops were greater than that for ploughed crops in 10 experiment years, but in 4 experiment years the opposite was the case, and in the remaining 31 experiment years the highest yield was at the same fertilizer level for both treatments. However, Riley *et al.* (1975) reviewed no-tillage research in the UK and concluded that, in general, optimum N fertilizer rates for no-tillage and cultivated crops probably do not differ greatly for non-legume crops. In a continuous no-tillage system, substantial amounts of fertilizer must be top-dressed, rather than mixed into the soil. Based on analysis of corn leaves, Shear (1969) and Triplett and van Doren (1969) reported consistently higher utilization of surface applied P and K fertilizer from untilled sod than from incorporated fertilizer. Similar results for P and K fertilizer were reported in the UK by Riley *et al.* (1975). It appears that roots growing near the soil surface under no-tillage systems are capable of supplying the P and K needs of corn.

Following the experiences of Adams *et al.* (1970) a series of field studies was initiated in 1969 on Cecil sandy loam to develop no-till techniques for growing corn (*Zea mays* L.) for grain in viable tall fescue (*Festuca arundinacea*, Shreb.). The principal objective was to combine no-tillage corn production in fescue with irrigation to provide summer grain production and winter and spring fescue forage production. Optimum management of fertility, irrigation, corn populations, and row spacing were developed to maintain productive fescue. Fescue competitive effects on corn grain yields from live, stunted, strip-killed, and killed fescue were evaluated along with measurements of micrometerological conditions in the double canopy. This report briefly illustrates some of the general findings and conclusions which are or will be reported in greater detail elsewhere.

IRRIGATED LIVE-STUNTED-KILLED FESCUE STUDY

Previous studies (Adams *et al.*, 1970) had indicated that corn could not be grown in stunted fescue and obtain consistent good grain yields with natural rainfall. It was hypothesized that if adequate irrigation water and plant nutrients were applied, plant competition effects could be overcome and good grain and fescue yields could be achieved. Therefore, during 1969 and 1970 an exploratory study was initiated to determine the influence of sod treatment, irrigation, and N level on fescue growth and corn grain yield, as reported by Carreker *et al.* (1972). In 1969, corn was grown with conventional tillage and in live fescue in rows 1 m apart with corn plant populations of 37 000 plants/ha. Fertilizer applied was 148 kg/ha N and 67 kg/ha P and K. Sprinkler irrigation treatments included (1) no irrigation; and irrigated when the top 30 cm of soil averaged (2) 1 bar, and (3) 5 bars suction. Delmhorst cylindrical gypsum electrical resistance blocks were installed in all plots at 10, 22, 37, and 53 cm deep. Highest corn yields, 8 523 kg/ha, were obtained with conventionally clean-tilled corn. Without irrigation this treatment produced only 1 637 kg/ha of grain. Corn planted in fescue sod produced grain yields of 4 603 kg/ha with irrigation and 35 kg/ha without irrigation. Corn grain yields were greatly reduced by competition with living fescue sod.

The 1969 study was redesigned in 1970 as reported by Carreker *et al.* (1972) to provide additional data on soil fertility and fescue sod treatment effects. Three replications of a randomized block design were used with rainfall and rainfall plus irrigation as main plots. Irrigation water was applied when the top 30 cm of soil averaged 1 bar suction. Sub-plots were killed, stunted, and live sod. The sod herbicide treatments at corn planting time were (1) 2.2 kg/ha atrazine and 0.28 kg/ha paraquat, (2) 2.2 kg/ha atrazine, and (3) no herbicide treatment to killed, stunted, and live sod, respectively. Sub-subtreatments were N rates of 112, 224, and 448 kg/ha with adequate P and K added according to soil test. Sub-sub-subtreatments consisted of corn planted at populations of 37 000 and 74 000 plants/ha in 51 cm rows. Fescue was clipped to a 4 cm height in all plots just prior to corn planting. Corn was planted with an Allis Chalmers no-till planter.

Grain yields were not satisfactory without irrigation, nor with irrigation in the live sod. Excellent yields were obtained in the stunted and killed sod with irrigation and high fertility. In the irrigated treatment with 448 kg/ha N and 74 000 plants/ha grain yields were 9 700 and 9 980 kg/ha for the stunted and killed sod, respectively. The 37 000 plants/ha with 448 kg/ha N gave grain yields of 8 000 and 7 200 kg/ha, respectively.

Fescue yields taken after corn harvest showed little grass regrowth in the killed treatment, more in the stunted sod, and a good growth in the live sod. Highest grass yield was obtained by the lowest N treatment for the corn with irrigation, apparently because the shorter and smaller corn allowed more sunlight to reach the grass in August and September. This study indicated a need for a better understanding of the interaction between corn grain yields, fescue production, and corn plant population.

CORN PLANT POPULATION—GRAIN AND FESCUE YIELD STUDY

In the 1972–73 season a study was conducted to evaluate the interaction between fertility level and corn plant population on corn grain and fescue forage yields, and relative light penetration through the corn canopy to the fescue canopy surface.[3] The purpose of the study was to produce corn grain in viable fescue sod and retain the fescue sod for winter forage production. The statistical design was a randomized block with three splits. The splits in their order were 102 and 51 cm row widths, plant spacings in the drill row of 15, 30, 45, and 60 cm, and three fertility levels. The fertility levels were poultry litter applied 14 days before planting at two rates, 9 and 18 MT/ha, and conventional fertilizer of 358, 134, and 134 kg/ha N, P, and K, respectively. The P and K were applied uniformly to all plots at planting to assure a non-limiting P and K status, and to permit evaluation of broiler litter as a N source. Nitrogen was applied in a split application with 150 kg/ha at planting and the remainder when corn was about 60 cm high. Plant nutrient content in poultry litter is variable as reported by Perkins *et al.* (1964) and Carreker *et al.* (1973). Average N, P, and K content of litter used in this study was 3.5, 1.6, and 2.0 percent, respectively. The 18 MT/ha poultry litter treatment received approximately 630, 288, and 400 kg/ha N, P, and K per year, respectively. The 9 MT/ha poultry litter treatment received approximately half these amounts.

Corn (Pioneer 3009) was planted in 20 cm wide killed fescue strips with an Allis Chalmers no-till planter. Fescue was killed with an herbicide formulation applied during the planting operation at the rate on sprayed areas only of 2.2 kg/ha atrazine, 0.28 kg/ha paraquat, and 375 kg/ha water. Delmhorst cylindrical gypsum blocks were placed at two locations and two soil depths, 13 and 23 cm, in representative sub-sub-subplots. Sufficient irrigation water was applied to reduce soil water suction in the top 30 cm of soil to less than 0.2 bar when the gypsum blocks indicated an average 1 bar suction.

The significant interactions between treatments for corn grain and fescue forage yields are shown in Tables 1 and 2. The highest grain yields were achieved with 18 MT/ha poultry litter, 30 cm plant spacings in the drill row, and 51 cm row widths. However, grain yield in the 51 cm row width and 30 cm drill row spacing was not significantly different from the 9828 kg/ha yield in the 102 cm row width and 15 cm plant spacing. Table 2 shows that fescue yields are significantly different for the 51 and 102 cm row widths. Best fescue yields were achieved with 102 cm row width. Furthermore, fescue yields significantly increased with wider plant spacings in the drill row. This indicates that plant nutrients and water were not limiting fescue growth, and that as fescue received more sunlight through the corn plant canopy fescue yields increased. Annual fescue yields were significantly less

TABLE 1. Corn grain yields as influenced by row width, drill row plant spacings, and fertility[a]

	Row Width[b] (cm)							
	51				102			
Plant Spacing[c] (cm)	15	30	45	60	15	30	45	60
	Yield kg/ha							
Fertility[d] N—P—K								
315-144-200[e]	6321	6469	6474	6278	5642	5813	5459	4683
630-288-400[f]	8711	10373	10207	8910	9828	8203	7048	6488
358-134-134[g]	6072	8982	8811	8002	7159	6767	5354	4847

[a] Width × Fertility × Spacing probability >F = 0.003.
[b] Probability >F = 0.0003.
[c] Probability >F = 0.0039.
[d] Probability >F = 0.0001.
[e] 9 MT/ha poultry litter.
[f] 18 MT/ha poultry litter.
[g] Conventional fertilizer, $^{LSD}.01 = 1375$ kg/ha.

[3] Harper, L. A., S. R. Wilkinson, E. R. Beaty, and J. E. Box, Jr. 1973. Corn-Fescue Cropping Systems for Increased Radiant Energy Use. *Agronomy Abstracts*. p 162. (unpublished).

TABLE 2. Fescue yields as influenced by years, row widths, plant spacing in drill row, and fertility

Year Effect		Row Width Effect		Spacing in Row Effect		Fertility Effect	
Years[a]	Yield (kg/ha)	Row Widths[b] (cm)	Yield (kg/ha)	Spacing in Drill Row[c] (cm)	Yield (kg/ha)	Fertility[d]	Yield (kg/ha)
						N—P—K	
1	6 761	51	4 170	15	3 981	315-144-200[e]	6 645
2	4 998	102	7 588	30	5 408	630-288-400[f]	5 729
				45	6 635	358-134-134[g]	5 263
				60	7 492		

[a]1972 and 1973, probability >F = 0.05.
[b]LSD_{05} = 685, probability >F = 0.0003.
[c]LSD_{05} = 515, probability >F = 0.0001.
[d]LSD_{05} = 517, probability >F = 0.0007.
[e]9 MT/ha poultry litter.
[f]18 MT/ha poultry litter.
[g]Conventional fertilizer.

for 1973 as compared to 1972, which indicates that fescue vigor and/or plant population was decreased by the preceding corn canopy. The 9 MT/ha poultry litter treatment gave a significantly higher fescue yield than did the 18 MT/ha treatment, implying that the more numerous corn plants in the highest fertility plots produced the greatest shading effect (Figs. 1 and 2).

Figs. 1 and 2 compare corn plant population and corn grain and fescue forage yields at the three fertility levels with relative light penetration to the fescue canopy surface. Relative light penetration is

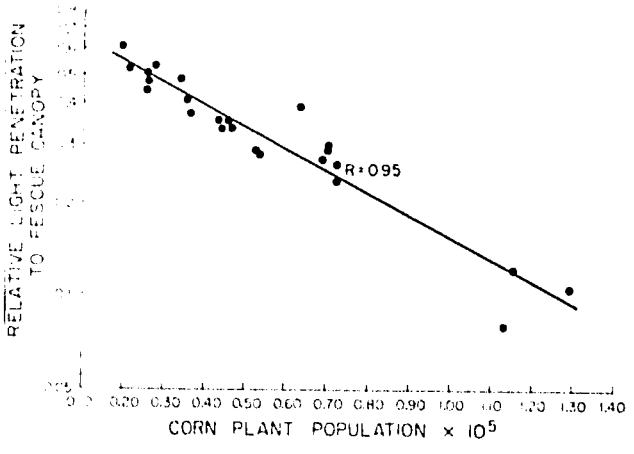

Figure 1. Relative light penetration through the corn canopy to fescue canopy surface, as influenced by corn plant population for all fertility levels and both row widths.

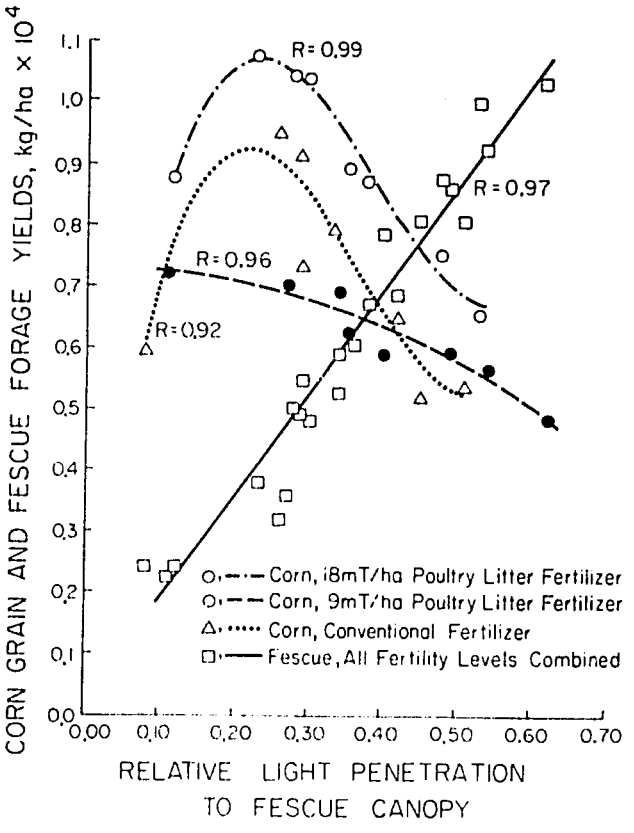

Figure 2. Corn grain yields for three fertility levels and fescue forage yields as related to relative light penetration to the fescue canopy surface.

the ratio of the within-canopy radiation at the fescue canopy surface to the above-corn canopy radiation. Radiation at the fescue canopy surface in each plot was measured by placing radiometers as described by Harper (1972), except that they were modified to measure incident rather than net radiation. Incident radiation immediately above the corn plants was measured with an Eppley pyranometer. Daily radiation measurements were made from two hours before to two hours after solar noon, and during the two-week period immediately following first corn tasseling.[4] Limitations on radiometers and data logging capability restricted light penetration measurements

[4]These relative light transmission data were taken when clear, mid-day solar radiation was approximately 1.4 ly/min.

to all plots in replications two and three. Data presented in Figures 1 and 2 are the two-year average for each treatment. Corn plant populations were not statistically significantly different between years or replications. Figure 1 shows the interaction between actual corn plant populations for all fertility treatments and both row spacings, with relative light penetration to the fescue canopy surface. The data represent plant populations from 129 257 to 19 734 plants/ha.

The relationships between corn grain yields, annual fescue forage yields, and fertility treatments with relative light transmission to the fescue canopy surface are shown in Fig. 2. Fescue yields ranged from approximately 2 000 kg/ha/year at 0.10 relative light transmission to 10 500 kg/ha/year at 0.65 relative light transmission. Fescue yields represent the total harvested growth under the corn canopy and regrowth during fall and winter prior to replanting corn. The relationship was linear and has a correlation of 0.97. The decreasing yields with decreasing relative light transmission were related to the fescue stand disappearance. There was not a statistically significant three-way interaction among fescue forage yield, fertility, and row spacing. Corn grain yield had a statistically significant interaction with fertility level. A curvilinear relationship existed in all cases between fertility level, relative light transmission, and grain yields. Curvilinearity increased with increasing fertility level.

Optimum grain and fescue yields were achieved at 0.30 relative light transmission at the fescue canopy surface (Fig. 2). This corresponds to corn plant population of approximately 60 000 plants/ha, and favors grain yields. Grain yields were 10 500, 7 000, and 9 200 kg/ha for 18 and 9 MT/ha poultry litter, and the conventional fertilizer treatments, respectively. Annual fescue yield was approximately 7 000 kg/ha for the 60 000 plants/ha population. The best overall corn grain and annual fescue yields were achieved with high fertility, adequate soil water, 102 cm row widths and plants spaced 15 cm apart in the row (60 000 plants/ha).

1973–75 WATER REQUIREMENTS STUDY

In 1973 a three-year study was initiated on strip killed and completely killed fescue sods to evaluate irrigation requirements. All plots had the same corn plant populations and fertility levels. Corn plant populations were approximately 60 000 plants/ha and fertilized with 458 kg/ha N each year. N was applied to all plots, except the 5 cm per week irrigation treatment, in split applications of 168 and 290 kg/ha at corn planting and when corn was 60 cm high, respectively. The 5 cm per week irrigation treatment received 458 kg/ha N in four equal applications and was applied when the corn was 4, 8, 12, and 16 weeks old. The 5 cm/week treatment was intended as a simulated sewage effluent treatment, and was included to evaluate possible effects of excessive water applications. The first year 112 P and 224 K kg/ha were broadcast prior to corn planting. In subsequent years P and K were broadcast annually prior to corn planting at the rate of 112 kg/ha each. The statistical design was a randomized block with six splits and replicated three times. The first split was a 20 cm strip of killed and completely killed fescue sod. Winter rye was planted on the completely killed fescue plots each year, following corn. Each rye and fescue plot was split five times to accommodate five soil water treatments. The five splits gave plots eight rows, 102 cm wide and 600 cm long with a minimum of 3 border rows between plots. Yields were obtained for 400 cm of the two middle rows. Atrazine and paraquat were applied to kill fescue at the same rates as used in the previously described experiments, and corn was planted (Pioneer 3009, 1973; 309B, 1974; and 3147, 1975) as described in the plant population, fertility, and row width study. Delmhorst cylindrical gypsum moisture blocks were placed 10, 22, 37, and 53 cm deep at three sites in all plots. Block readings were taken three times each week. When the desired soil water levels were reached in each plot irrigation water was added with sprinklers to reduce soil water suction to less than 0.2 bars in the top 40 cm of the soil profile. There were five soil water treatments: (a) natural rainfall only, (b) 5 cm per week, (c) 1 bar, (d) 5 bars, and (e) 15 bars. Water was applied to the irrigation treatments when the 10 and 22 cm moisture block averaged the desired soil water suction value.

Three-year average corn grain yields and irrigation and rainfall water during the corn growing season are shown in Fig. 3. Grain yields were not significantly different for years or replications. There was no significant difference in the 1 and 5 bar treatments. The completely killed sod treatment gave significantly higher yield in all cases except for the 5 cm per week treatment. Weeds (crabgrass, *Digitaria sanguinalis*) became a problem in the completely killed 5 cm per week treatment. Grain yields for the 1 bar treatment averaged 10 166 and 8 660 kg/ha for the completely killed and strip killed treatments. There was 42.5 cm average rainfall on all plots during the growing season and the 15 bar, 5 bar, 1 bar, and 5 cm per week plots received 8.6, 14.0, 19.7, and 77.8 cm irrigation water, respectively.

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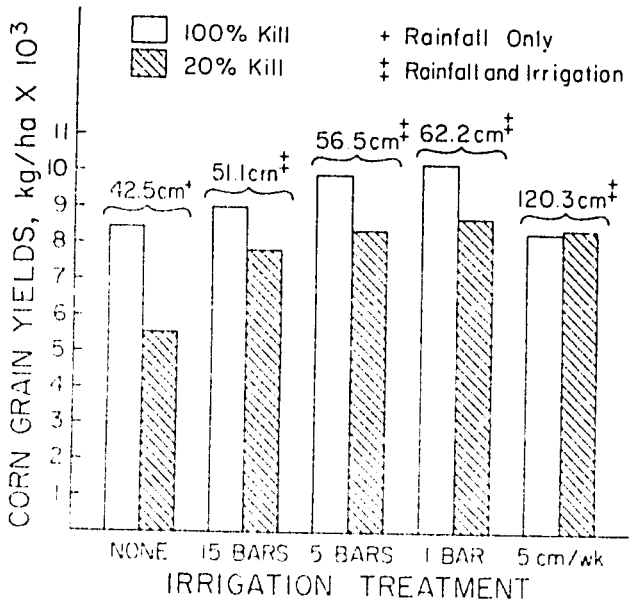

Figure 3. Corn grain yields on 100% and 20% killed fescue, as influenced by irrigation treatment.

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DISCUSSION

E. R. Leng (AID, USA). Is irrigation economical in the (Piedmont) area?

Box. In a recent bulletin of the Georgia Extension Service it is indicated that for a cable-towed, high-volume irrigation gun—which is probably the type that's best adapted for irrigation in this hill area of the Piedmont—the cost for 5 inches of water is approximately $45 per acre.

63.
Tillage Options for Corn Production on Sloping Topography

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Since man began cultivating to enhance food production, tillage has been a very important aspect of crop production. Changes in tillage tools began more than 200 years ago in France with improvements on the plow. This was further refined by Thomas Jefferson who designed what has been referred to for the last 200 years as the moldboard plow.

In the United States during the 1930's and early 1940's some effort was directed towards decreasing tillage through changes in equipment. At that time herbicides were not available. In the 1950's attention was directed towards reduced tillage after plowing as a means of reducing cost, improving water use efficiency, and decreasing soil erosion. In the early 1960's two main research areas became evident and resulted in innovative approaches in tillage. Much effort was directed towards developing equipment to place seed in unplowed soil regardless of the crop residue on the surface (Triplett *et al.*, 1963). At the same time, herbicides were developed to kill vegetation at the time of crop establishment and to suppress weed competition throughout the growing season.

Major changes took place in agriculture during the same period. Farm units became larger, with more monoculture. Larger equipment was used to till larger areas in less time.

The amount of tillage used for crop production has caused much concern. Each year, conventional tillage methods move enough soil in the United States to build a freeway from the East to the West Coast. This is a matter of concern since it requires considerable investment in equipment and fuel. Additional concerns relate to the influence of the tillage system on the ability of farmers to effectively control potential soil losses.

Research work in many states showed that decreased tillage did not necessarily result in decreased corn yields. In many situations, reduced tillage improved the opportunity for profitability. Research by private industry and public research institutions dramatically affected the practices available for crop production. One of the earliest indications of this was the shift in sale of tillage equipment. In the 1960's, the sale of plows began to decrease in relation to other tillage tools such as the chisel and field cultivator.

In Ohio, as in other states, research was directed not only toward reduced tillage but also to no-tillage. This included an array of tillage practices that could be called minimum, conservation, and conventional tillage (Bone *et al.*, 1976). Studies were carried out on sloping topography in eastern and southern Ohio over a range of climatic and soil conditions. On Wooster silt loam (Typic Fragiudalf fine-loamy), a well-drained soil with average May through September rainfall of 5[illegible] cm, reduced tillage led to an increase in yield (Table 1). Yield increases were observed for continuous corn, corn-soybean and corn-oats-meadow sequences.

TABLE 1. Average grain yields of corn for tillage systems and crop sequence; all plots maintained continuously by the prescribed tillage treatment (13 years). Wooster silt loam. Ohio Agricultural Research and Development Center, Wooster, Ohio (81° 56′W, 40° 47′N)

	Corn Yields (kg/ha)		
Tillage	Continuous Corn	Corn-Soybean Rotation	Corn-Oats-Hay Rotation
Plow-disc			
Plant-cultivate	6940	7000	7940
Plow-plant			
Cultivate	7120	7180	8000
No-tillage	8300	8240	8360
LSD 0.05	440	440	440

This response in corn yield is typical of those found in southeastern Ohio farm demonstrations on soils that have water status within the root zone that does not impair crop growth. These soils occur on slopes up to 18% and have a medium surface texture (silt loam or loam) which provides maximum opportunity for storage of available water throughout the growing season. Water storage is enhanced by residue cover (60 to 80%) on the surface.

Soils on less sloping topography (2–6%) may have water status within the root zone that affect date of planting and crop growth. The subsoils are generally saturated early in the spring, but by mid-April

in Ohio most of this saturated condition tends to disappear. An example is Rossmoyne silt loam (Aquic Fraguidalf fine-silty). There is little response to intensity of tillage on this soil (Table 2), which has an average rainfall of 61 cm from May through September. This raises a concern as to the selection of a tillage system for a specific soil and climate situation. What criteria should be used for selecting the tillage system?

TABLE 2. Average grain yields of corn for tillage treatments for continuous corn. Average of one 7-year and one 2-year study on Rossmoyne silt loam. Ohio Agricultural Research and Development Center. Southern Branch, Ripley, Ohio (83° 47′W, 38° 47′N)

Tillage	With One Cultivation	Without Cultivation
	kg/ha	
Plow-disc-plant	8820	8880
Rototil 15 cm-plant	8880	8750
Disc 10 cm-plant	8700	8700
Chisel plow 22 cm-plant	8800	8820
No-tillage harvesting corn for silage		8820
No-tillage harvesting corn for grain		8840
LSD 0.05	630	630

In tillage system selection it is important that the area be characterized according to rainfall during the growing season and soil properties including internal drainage, texture, and slope. Soil texture relates both to available mositure and to potential for crusting. The following criteria have been used as guidelines in the selection of tillage systems in Ohio:

1. Grain yield. (If the grain yield is higher with reduced tillage there is a tendency to select this system without regard to other criteria.)
2. Cost of the tillage system.
3. Effectiveness of the tillage system in controlling soil erosion.

Economic studies by the Department of Agricultural Economics and Rural Sociology, The Ohio State University, have indicated that in a corn-corn sequence, costs are reduced and profits are increased by reduced tillage. Costs were based on the same yield response for all tillage systems, and showed a profit advantage per ha of about $17 for the chisel plow and about $36 for no-tillage compared with a conventional tillage system (Table 3). However, there are situations where the yield of no-tillage may be higher (Table 1) than the yield with conventional tillage. This adds a new dimension to the

TABLE 3. Ohio corn production budgets per ha, 1976, Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus

	For Yield Level of 8700 kg/ha	
Tillage System	Total Expenses	Profit and Return to Management
Conventional	$667.75	$294.75
Chisel plow	$650.79	$311.73
No-tillage	$631.40	$331.10

economics of tillage system selection. In a recent study of yield response of corn following corn on soils on sloping topography (Tables 1 and 2), the profitability ranged from $30.00 to $97.50 per ha depending upon the yield increase with reduced tillage (Foster *et al.*, 1976).

Data from the Agricultural Research Service, Coshocton, Ohio (Harrold, 1971), indicate that no-tillage came close to eliminating soil loss by erosion compared to conventional tillage under the same rainfall conditions and soil properties.

The Universal Soil Loss Equation (Wischmeier, 1965) serves as a guideline in determining the effectiveness of tillage systems in decreasing potential soil loss. An Ohio adaptation has been made of the Universal Soil Loss Equation (Nolte *et al.*, 1975). The following example is taken from Nolte *et al.*:

> Wooster silt loam occuring on a 3% slope 76.2 m long has a T soil loss value of 9000 kg/ha. Using a crop sequence of continuous corn under climatic conditions in eastern Ohio and conventional tillage without conservation practices produces a potential soil loss of 16700 kg/ha. A chisel-plant system produces approximately 6110 kg/ha soil loss, while a no-tillage system produces a potential soil loss of 3000 kg/ha.

RECOMMENDATIONS

There are several steps which can help to enhance the success of the selection and carrying out of an appropriate tillage system for a specific soil and climatic location.

The hybrid selection is exceedingly important. With reduced tillage systems soil temperatures may be lower than with conventional systems. A hybrid should be used that has the ability to germinate and grow at temperatures near 12°C and has seedling vigor that will enhance emergence under a wide range of soil surface conditions of roughness and of residue cover. In Ohio, percent emergence is used as a guide in selection of a hybrid for no-tillage. This is listed in Corn Performance Tests (Jordan, 1975). The fertility aspect of the crop must be met

in such a way as to enhance optimum yield response based on a soil test for the yield response anticipated.

Early planting for optimum yield also increases profitability: hybrids are available that will respond to earlier planting dates, and earlier planting does have increased yield response.

The hybrid selected must be planted at a seeding rate for the optimum yield response. In addition to this, the planter must place the seed in the soil over a wide range of soil condition at a depth of approximately 3.7 to 5.0 cm.

The use of insecticides is important to obtain desirable plant stands. This may involve both a seed treatment in the seed box plus placement of insecticide over or in the row at planting time. Insecticides must be selected with a target species in mind.

The spraying equipment used to apply herbicides is an important part of the tillage program. This phase begins with the identification of the vegetation to be controlled and selection of the herbicides. The application of material in an effective manner and rate is a critical aspect of vegetation control.

Even after these steps have been followed, it is very important to make observations in the field to see if plant stands have been accomplished, nutritional needs have been met, herbicides have been applied properly, and insecticides used are effective.

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DISCUSSION

H. F. Massey (Kentucky, USA). How widely is this technique being used on suitable land in Ohio? What percentage of land is being planted by this method?

Bone. In some eastern Ohio counties where the demonstrational programs described by Underwood have been going on, the corn acreage is 70 or 80% no-tillage corn. It varies, but the method has been well accepted where it was introduced in the demonstrational program.

E. R. Leng (AID, USA). What's the disadvantage? Why isn't it used more widely?

Bone. The disadvantage probably relates to tradition. The skill involved in these systems is somewhat more than in other techniques and this may be why more people have not adopted them. Where we work with an individual in a demonstration program for the first year, this gets him over the humps and into the system pretty well.

Leng. How about planting speed?

Bone. Planting speed in a no-tillage system will be less than with a conventional system. Most planters now with plateless units are designed to plant at 7 or 8 miles an hour, which is about double what should be used for no-tillage. There are definite detrimental effects to planting fast.

64.

Factors Influencing Hazelnut Production in the Giresun and Ordu Provinces of Turkey: An Analysis of Relative Efficiency Based on the Profit Function

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INTRODUCTION

Ordu and Giresun provinces are in the northeast of Turkey on the Black Sea coast. Both provinces have a land structure which rises very fast from sea level to mountains without passes in the south, some of which are over 3000 m. Limited cultivatable lands are restricted to the northern slopes and to the low belt near sea level. The region is one of the most densely populated areas in Turkey. In the two provinces, density of population rarely falls below 50 people per sq. km. and can go up as high as 250 people per sq. km. Such high densities of population, coupled with limited land, give rise to considerable migration. The people from the northeast are stereotyped as industrious, business-like and clannish in behavior. Given the extreme scarcity of and pressure on the resources of the region, such behavior would be only fitting, if only as a prerequisite of survival (Ministry of Reconstruction and Settlement, 1972).

The economic livelihood of the population, about 85 percent of which is rural, is derived mainly from three agricultural products which are exported abroad or to other regions of Turkey: tobacco, hazelnuts, and tea (Ministry of Reconstruction and Settlement, 1972). Ordu and Giresun specialize in hazelnuts. Hazelnuts are among the significant export items of Turkey, and Turkish hazelnuts are sought in world markets as being of high quality.

Our aim in this paper is to look at various factors which can be hypothesized as having an effect on the efficiency of hazelnut production. The tool of analysis that we shall employ is the profit function as developed by Lau and Yotopoulos (1971). The data that we shall utilize are based on a survey conducted in Giresun and Ordu in 1970 by the Turkish Ministry of Agriculture. Limited use was also made of another survey conducted in 1974 by Fiskobirlik, the hazelnut cooperative, in Giresun and Ordu. The same data were the basis of one of the authors' Ph.D. dissertation [Kasnakoglu, 1972].

EFFICIENCY AND THE PROFIT FUNCTION

Whatever the criteria of differentiation between economic units or sets of economic units, a criterion of relative economic efficiency should account for three factors (Lau and Yotopoulos, 1972):

a. Technical efficiency; different production units can produce different levels of output from given inputs.

b. Price efficiency; different production units will differ in their success in maximizing profits.

c. Different economic units face different output and input prices.

> "It is clear that two firms of equal technical efficiency which have successfully maximized profits would still have different values or profits as long as they face different prices" (Lau and Yotopoulos, 1972).

Usually, the production function is utilized as a tool in the analysis of economic efficiency. However, because it cannot account for the factors stated above, the production function is an inadequate tool in this respect (Yotopoulos, Lau, and Somel, 1970).

A more efficient tool for the analysis of economic efficiency, especially for the purpose of comparing different forms grouped according to various criteria, is the profit function. As the theory of the profit function has been dealt with in detail elsewhere (Lau and Yotopoulos, 1971, 1972; and Yotopoulos and Lau, 1973), we will present only an outline here.

Given a production function

$$Q = f(S, Z)$$

where Q is output, X is the row vector of variable inputs, and Z is the row vector of fixed inputs, profit, P, is defined as current revenues minus current costs,

$$P = pQ - X\hat{c}'$$

where p is the price of output and $\hat{c}$ is the row vector of variable input prices.

Based on the assumptions of the optimization process, it is possible to obtain a profit function

$$\hat{\Pi} = g(p, \hat{c}, Z)$$

which gives a relationship between the maximized value of profits for each set of p, $\hat{c}$ and Z.

It is possible to reduce the relationship to a Unit-Output-Price (UOP) profit function,

$$\frac{\hat{\Pi}}{p} = \Pi = g(c, Z)$$

where $c = 1/p\ \hat{c}$ is the row vector of normalized variable input prices (Lau and Yotopoulos, 1971).

With the UOP profit function, tests for relative efficiency can be held by testing some of the parameters. This is best illustrated by specifying a functional form. For a Cobb-Douglass production function

$$Q = A \prod_{i=1}^{m} X_i^{\alpha_i} \prod_{j=1}^{n} Z_j^{\beta_j}$$

where

$$\mu = \sum_{i=1}^{m} \alpha_i < 1,$$

the UOP profit function is

$$\Pi = A \prod_{i=1}^{m} c_i^{-\alpha_i/(1-\mu)} \prod_{j=1}^{n} Z_j^{\beta_j/(1-\mu)}$$

By differentiating between the profit functions of different groups of firms, it is possible to test different facets of relative economic efficiency by conducting certain tests on the parameters A, α_i and β_j.[1]

A test of equal relative economic efficiency can be held by testing if the coefficient A differs between groups of firms. In a Cobb-Douglas specification this test is achieved by testing in a linear logarithmic estimation whether a dummy variable representing a grouping of firms is significantly different from zero or not.

Below, we shall represent several such tests on hazelnut farms grouped according to various criteria.

THE DATA AND FUNCTIONAL SPECIFICATION

The data are specified in detail in Kasnakoglu (1975). Here, we shall give only a general description. The sample that was used in our study consists of 202 hazelnut farms. A certain plot in each farm is included in the analysis according to the survey design. For each plot we define profits (PRF) as the difference between the total value of the product (TVP), and total wages (TW) for hired and family labors utilized in production and harvesting, plus total current and capital expenditures in monetary terms (TCAP). Family labor is valued in terms of opportunity cost as equivalent to hired labor. Current and capital expenditures include such things as fertilizer, pesticides, depreciation, etc., all converted to monetary terms. The price of labor is wages and the price of current and capital expenditures is taken as the opportunity cost of such expenses, $(1 + r)$ where r is the interest rate. The normalized prices of these variable inputs are labeled as WT and FT respectively. The fixed factors of production are the number of hazelnut trees in the plot (TOCAK) and the area of the plot (CSHA). Hence, with the prefix L depicting natural logarithms, the estimating form becomes

$$\text{LPRF} = A + a_1\,\text{LWT} + a_2\,\text{LFT} + b_1\,\text{LTOCAK} + b_2\,\text{LCSHA} + \Sigma d_i D_i.$$

As stated above, the variable TCAP incorporates as an aggregate both current nonlabor expenditures and service flows from capital inputs. At the time of this study it was not possible to disaggregate the data. Hence, we conducted the exercise of an alternative specification, viz. the specification of TCAP as a fixed factor of production. Then the profits in this alternative specification, denoted as PRFA, are defined as the difference between TVP and TW. The estimating form of the profit function in this alternative specification is

$$\text{LPRFA} = A' + a_1'\,\text{LWT} + b_1'\,\text{LTCAP} + b_2'\,\text{LTOCAK} + b_3'\,\text{LCSHA} + d_i' D_i.$$

(Please refer to the appendix for the specification of the variables.)

TESTS OF HYPOTHESES

We consider nine criteria which can be hypothesized to be effective factors in creating differences in economic efficiency. These are:

1. Total family size.
2. Total land area of the farm.
3. Place of sales.
4. Time of sales.
5. Channel of sales.
6. Total hazelnut area of the farm.
7. Province, as representing the quality of soil.
8. Altitude of the surveyed field.
9. Average age of trees on the surveyed field.

Hypotheses with respect to these criteria will be given below. In general, the profit functions appear well behaved. However, the initial specification as presented in Table 1 indicates that the wage rate variable is statistically insignificant in most cases. The rest of the variables are significant and have the right signs in both specifications. A method of establishing preference over one of the specifications can be looking at the duality relationships between

[1] It is possible to test between groups of firms for: (a) equal relative economic efficiency, (b) equal relative technical and price efficiency, (c) absolute price efficiency in each group, and (d) constant returns to scale. Due to computer program limitations we could not conduct all those tests, so confined ourselves to the test of equal relative economic efficiency only.

TABLE 1

Regression	A	LWT	LFT	LTOCAK	LCSHA	D1	D2	D3	D4	R^2
1. No dummy	0.5638	−0.0487	−1.1045	0.3525	0.4801					0.4681
	I	I								
2. Total family size	0.5374	−0.0231	−1.0995	0.3575	0.4719	0.1249				0.4707
	I	I				.75				
3. Total Land A	0.9477	−0.0559	−1.0268	0.3488	0.4372	−0.2132				0.4733
	.75	I								
4. Total Land B	0.4478	−0.0728	−1.1033	0.3553	0.5045	0.1102				0.4694
	I	I				.75				
5. Total Land C	0.8409	−0.0960	−1.0088	0.3476	0.4675	−0.0804	−0.2573			0.4766
	.75	I				I	.90			
6. Place of sales	0.4496	−0.0460	−1.1705	0.3621	0.4667	−0.0896				0.4692
	I	I				I				
7. Time of sales	0.4916	0.0807	−1.2153	0.4210	0.4338	−0.3364				0.4766
	I	I								
8. Sales channel	0.5835	−0.0468	−1.0959	0.3506	0.4809	0.0148				0.4681
	I	I				I				
9. Total hazelnut area	0.2389	−0.0321	−1.2130	0.3589	0.5198	0.1670	0.1271	−0.0709	0.0797	0.4729
	I					I	I	I	I	
10. Province	−0.6615	0.1544	−1.6873	0.5298	0.3073	−0.4567				0.4950
	.75	I								
11. Altitude	0.4419	−0.0517	−1.736	0.3818	0.4599	−0.0383	−0.1502	−0.2438	−0.2479	0.4749
	I	I				I	.75	.75	.75	
12. Average age of trees	−0.7018	−0.0552	−1.4869	0.4625	0.3441	−0.1065	0.5146	0.4109		0.5085
	.75	I								

TABLE 2

Regression	A′	LWT	LTCAP	LTOCAK	LCSHA	D1	D2	D3	D4	R^2
1. No dummy	1.8644	−0.4380	0.2199	0.3405	0.3856					0.6061
2. Total family size	1.8592	−0.4214	0.2173	0.2436	0.3828	0.0660				0.6071
		.90				.75				
3. Total land A	2.0549	−0.4139	0.2218	0.2352	0.3566	−0.1356				0.6092
		.90				.75				
4. Total land B	1.7609	−0.4582	0.2214	0.2426	0.4049	0.0912				0.6074
						.75				
5. Total land C	1.9484	−0.4379	0.2245	0.2369	0.3781	−0.0338	−0.1691			0.6119
						I	.90			
6. Place of sales	1.8682	−0.4357	0.2198	0.2400	0.3864	0.0054				0.6061
		.90				I				
7. Time of sales	1.8697	−0.4018	0.2226	0.2815	0.3566	−0.2023				0.6105
		.90				.75				
8. Channel of sales	1.9051	−0.4162	0.2187	0.2350	0.3886	−0.0441				0.6066
		.90				I				
9. Total hazelnut area	1.7385	−0.4756	0.2241	0.2397	0.4083	0.0889	0.0543	−0.0716	0.0732	0.6095
						I	I	I	I	
10. Province	1.4636	−0.5207	0.2270	0.3349	0.2917	−0.2434				0.6186
11. Altitude	1.8305	−0.4733	0.2229	0.2653	0.3612	−0.0676	−0.1331	−0.2293	−0.2706	0.6147
						I	.75	.90		
12. Average age of trees	1.2430	−0.5967	0.2251	0.3125	0.2948	−0.0771	0.3377	0.2633		0.6321

the profit function and the production function coefficients. However, this requires further tests for conclusive results. As stated above in footnote 1, these tests could not be conducted. Hence, we present both specifications. It can be observed that the indicators of relative efficiency, the signs and significance of the dummy variables are quite invariant between the two specifications. And, as relative efficiency is our main concern, we will turn to the hypotheses and analyze each one briefly. In each case, the reader is referred to the appendix for numerical results.

Hypothesis I. As hazelnut production is quite a labor intensive process, it can be hypothesized that larger families, utilizing this larger family labor more intensively, would be more efficient. This hypothesis is acceptable according to Regressions 2. However, the margin is small; a factor of 7–13 percent and quite a low level of significance. Hence, this result should be viewed cautiously. (A similar line of analysis, using a weighting scheme for the different members of the family, did not improve the results.)

Hypothesis II. The total size of a farm is usually a crucial variable in economic analysis. The usual controversy is around two views:

(a) Large farms, though being more capital intensive in a labor-abundant environment, make up for this by having better access to credit, technological information, and other scarce inputs. Hence, larger farms can be expected to be more efficient.

(b) Small farms, using family labor in the farm intensively, usually establish better managerial performance. Hence, small farms can be expected to be more efficient.

Although our bias is towards the latter view as a result of our empirical experience, we do believe that the problem requires the utmost scrutiny and care. We will show this with a little exercise that we conducted. Regressions 3 (Case A) indicate that if the border-line is taken as 25 decares, small farms are relatively less efficient. However, Regressions 4 (Case B), in which we take 10 decares as the borderline, show that small farms are relatively more efficient. The crucial thing then is to be rid of one's biases and determine borderlines empirically in an interactive manner. Regressions 5 (Case C) joined Cases A and B, and we observed that medium sized farms between 10 and 25 decares were at a disadvantage in employing labor in a larger area and at the same time were unable to use some of the implied financial and informational economies of scale, thus making them relatively less efficient than smaller and larger farms.

Hypothesis III. Considering costs of transportation, one would expect that the closer the sales take place to the field, the more efficient the operations. Regressions 6 indicate that this factor is not effective, and the place of sales is rejected as an efficiency criterion.

Hypothesis IV. Hazelnuts are sometimes sold on the tree, before they are harvested. This is due to the cash needs of growers, as well as to the structure of support prices (see Kasnakoglu [1975], Appendix F). One would expect that those who sell exclusively after the harvest would be more efficient because cash needs usually lead to exploitation by money lenders. We get diametrically opposite results from Regressions 7. This might be attributed to minimizing the risk of uncertainty about future prices. However, our tests are not indicative of any unequivocal explanation in this respect.

Hypothesis V. We compared the relative efficiency of farmers who sell their produce exclusively to the Fiskobirlik cooperative with those who sold to merchants, middlemen and Fiskobirlik, i.e., who had diversified sales channels or non-cooperative sales channels. The indication was that this was not a significant dimension for purposes of relative efficiency comparisons.

There is substantial correlation between farmers who sell after the harvest and farmers who sell to the cooperative. The results of hypotheses IV and V might suggest that the cooperative is not playing a strong and competitive role in the market. Further tests in this vein can shed light on this issue.

Hypothesis VI. A hypothesis similar to hypothesis II was tested with respect to total hazelnut area in a farm. There is not a one-to-one correspondence between total farm size and total hazelnut area. Furthermore, total farm size must be the dominating factor. Various trials with total hazelnut area all lead to its rejection as a factor of efficiency. Regressions 9, in which all class dummies are not significantly different from zero, is one example of our trials.

Hypothesis VII. The land structure and soil quality of Ordu are superior to Giresun. In some cases the slope in Giresun is as high as 70 percent, whereas rarely over 40 percent in Ordu. Furthermore, Ordu is a newer hazelnut production area with younger trees. These considerations indicate that farms in Ordu would be more efficient. The results of Regressions 10 support this hypothesis.

Hypothesis VIII. Technical considerations of production, as well as proximity to urban centers along the coast, transportation facilities, etc., lead to the hypothesis that the higher a farm, the less efficient it becomes. This hypothesis seems acceptable according to the results of Regressions 11.

Hypothesis IX. The productivity of hazelnut trees increases up to around the age of 25 years and then decreases. A hypothesis of initially increasing and

then declining efficiency according to the average age of trees in the plot is supported by Regressions 12.

CONCLUSIONS

Our results lead us to generalize tentatively that hazelnut producers are not differentiable in terms of relative efficiency with respect to predominantly economic factors, whereas natural factors do cause differences in relative efficiency. It will be possible to conduct further tests to pinpoint other dimensions of efficiency. Our results are tentative and preliminary until these future plans are realized.

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APPENDIX

Profit Function Estimates—Regression Analysis Variables (L signifies natural logarithms).

- A or A': Constant term for intercept.
- LWT: Wage rates per hour in Turkish Liras (T.L.) divided by price of output.
- LFT: Cost of capital; $1 + r$ where r is the interest rate, divided by price of output.
- LTCAP: Current and capital inputs (service flows) in T.L.
- LTOCAK: Number of hazelnut trees.
- LCSHA: Surveyed hazelnut area in decares (1 decare = 0.247 acres).

Dummy variables:

Regression 2: Total Family Size (TFPOP).
$D1 = 1$ for TFPOP > 8.
TFPOP ≤ 8 is absorbed in the intercept.

Regression 3: Total Land Owned in Decares (ITTA); Case A.
$D1 = 1$ for ITTA ≤ 25
ITTA > 25 is absorbed in the intercept.

Regression 4: Total Land Owned in Decares (ITTA); Case B.
$D1 = 1$ for ITTA ≤ 10
ITTA > 10 is absorbed in the intercept.

Regression 5: Total Land Owned in Decares (ITTA); Case C.
$D1 = 1$ for ITTA ≤ 10
$D2 = 1$ for 10 < ITTA ≤ 25
ITTA > 25 is absorbed in the intercept.

Regression 6: Place of Sales (PLACE).
$D1 = 1$ for sales at the field or village or both. Sales at any other place (such as the town or the city) is absorbed in the intercept.

Regression 7: Timing of Sales (TIME).
$D1 = 1$ for sales after the harvest.
Sales before the harvest or sales both before and after the harvest are absorbed in the intercept.

Regression 8: Channel of Marketing (MARKET).
$D1 = 1$ for sales to the Fiskobirlik Cooperative. Sales to various places or to places other than the cooperative (middlemen, merchants, etc.) are absorbed in the intercept.

Regression 9: Total Hazelnut Area Owned, in Decares (CTHA).
$D1 = 1$ for CTHA ≤ 5
$D2 = 1$ for 5 < CTHA ≤ 11
$D3 = 1$ for 11 < CTHA ≤ 20
$D4 = 1$ for 20 < CTHA ≤ 30
CTHA > 30 is absorbed in the intercept.

Regression 10:
$D1 = 1$ for Giresun. Ordu is absorbed in the intercept.

Regression 11: Altitude, in Meters (HGT).
$D1 = 1$ for 50 < HGT ≤ 250
$D2 = 1$ for 250 < HGT ≤ 350
$D3 = 1$ for 350 < HFT ≤ 550
$D4 = 1$ for 550 < HGT
HGT ≤ 50 is absorbed in the intercept.

Regression 12: Average Age of Hazelnut Trees in Years (AGE).
$D1 = 1$ for AGE ≤ 10
$D2 = 1$ for 10 < AGE ≤ 20
$D3 = 1$ for 20 < AGE ≤ 50
AGE > 50 is absorbed in the intercept

The estimated linear-logarithmic form in Table 1 is

$$\text{LPRF} = A + a_1\,\text{LWT} + a_2\,\text{LFT} + b_1\,\text{LTOCAK} + b_2\,\text{LCSHA} + \Sigma d_i D_i.$$

The estimated linear-logarithmic form in the alternative specification presented in Table 2 is

$$\text{LPRFA} = A' + a_1'\,\text{LWT} + b_1'\,\text{LTCAP} + b_2'\,\text{LTOCAK} + b_3'\,\text{LCSHA} + \Sigma d_i' D_i$$

In the tables below, all the coefficients are significantly different from 0 at a probability level ≧ .95, except where indicated under the coefficients by:

- .90, implying significant difference from 0 at probability level ≥ .90, but not at probability level ≥ .95;
- .75, implying significant difference from 0 at probability level ≥ .75, but not at probability level ≥ .90;
- I, implying insignificant difference from 0 at probability level ≥ .75.

All F-values indicate significance at probability level ≥ .995.

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65.
Cropping of *Lupinus* Species on Hill Lands in Sub-Tropical Areas on the East Coast of Australia

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A considerable proportion of the sub-tropical areas on the east coast of Australia is undulating to hilly. For example, in the Richmond-Tweed Region (28°17′-29°25′ S, 152°35′-153°35′ E), on the north coast of New South Wales, about one-quarter of the area consists of moderate slopes (3-8% slope) and a further one-fifth consists of steep hills (8-30% slope) (Anon., 1972). Near the coast, in the higher rainfall areas, much of the hill land is utilized for either non-agricultural activities or intensive enterprises such as horticulture. In areas away from the coast, much of the hill land of 3 to 30% slope has been cleared of timber. The pastures consist of warm climate species, the dominant one being carpet grass (*Axonopus affinis*).

The region lies in a transitional zone between tropical and temperate climates. From November to March, warm humid conditions associated with the northerly winds prevail and tropical cyclones can occur, while from July to September the weather pattern is dry with some occurrence of frost. Average annual rainfall on the coast is 1 650 mm, and this decreases to 1 025 mm in the west of the region.

December and January are the hottest months and July is the coldest (Anon., 1972). Temperatures along the coast are modified by sea temperatures, but there is little variation along the valley floors (Murtagh *et al.*, 1975). Hill land temperatures and frost incidence are dependent on local effects such as topography, aspect, slope, soil type, soil moisture content, and the type of vegetative cover. On the average, evapotranspiration exceeds rainfall from July to December, at least for areas away from the coast.

The main feature of the soils in the region is the great variation in types (McGarity, 1956). Those hill soils developed on ferruginous parent rock are generally well structured, have a moderate to high fertility and are amenable to pasture improvement. Those hill soils developed on non-ferruginous, quartz-rich parent rock generally have poor structure, low pH, and low fertility. Little in the way of pasture improvement has been done with the latter, although cool climate legumes can be oversown successfully.

The major enterprises on hill lands are beef production and dairying. One of the major limiting factors to high animal production is low pasture production from the warm climate species during winter and spring. Cool climate perennial pasture species grow well in autumn and winter but are rapidly replaced by warm climate species in summer (Colman and Mears, 1975). The danger of serious erosion precludes cultivation for forage crops, although annual cool climate legumes can be successfully oversown into pastures dominated by warm climate grasses using sod-seeding machinery (Murtagh *et al.*, 1964). No technology is yet available for the growing of cash crops on hill lands in this environment. Therefore an experiment was conducted to evaluate a number of lupine (*Lupinus spp.*) species for forage and grain (cash crop) production.

MATERIALS AND METHODS

The experimental site (28°50′ S, 152°52′ E) was on chocolate soil (Stace *et al.*, 1968) on a hillside with a southerly aspect. This soil is a friable brown

duplex type classified as Db 3.12 under the Northcote (1965) system. The dominant species in the base pasture was carpet grass.

Four lupine varieties were compared at four sowing rates in a randomized block design with three replications. The varieties and sowing rates, adjusted for seed size, were:

Variety	*Sowing Rates*
L. luteus cv. Weiko III	40, 80, 120, and 160 kg/ha
L. angustifolius cv. Unicrop	
L. albus line WBI	75, 150, 225, and 300 kg/ha
L. albus line WBII	

The site was mown prior to fertilizing and sowing. All plots received a basal fertilizer dressing of 37 kg of phosphorus ha^{-1} and 48 kg of sulphur ha^{-1}, both applied as superphosphate, and 50 kg of potassium ha^{-1} applied as potassium chloride. Fertilizer was applied through a sod-seeding machine. Plot size was 20 × 2 m and row width was 30 cm.

Seeds were inoculated with the appropriate rhizobial strain, lime pelleted, and then sown by hand on April 23, 1975. Plots were sampled for dry matter (DM) yield from 1 m^2 randomly placed quadrats on the following six occasions: June 24, July 8 and 22, August 5 and 26, September 16, 1975. The harvested material was weighed and two sets of subsamples taken; subsamples were dried at 80° C. One set of subsamples was bulked over replications and then analysed for total Kjeldahl N and *in vitro* dry matter digestibility (IVDMD). Extra subsamples from harvest two were separated into leaf and stem, dried, and analysed for IVDMD.

Grain yield estimates were taken, in mid-November, 1975, from the mean of three 1 m^2 quadrats per plot, and subsamples were analysed for N.

DM yield and grain yield data were subjected to an analysis of covariance with plant density as the covariate.

RESULTS AND DISCUSSION

Temperature for the experimental site and rainfall for Kyogle (6 km distant) are shown in Fig. 1. Comparisons of 1975 data with long-term means at other locations indicated that the 1975 monthly maximum temperatures were approximately 0.5 to 1.0° C warmer than the long-term means during May to July, and monthly minimum temperatures were

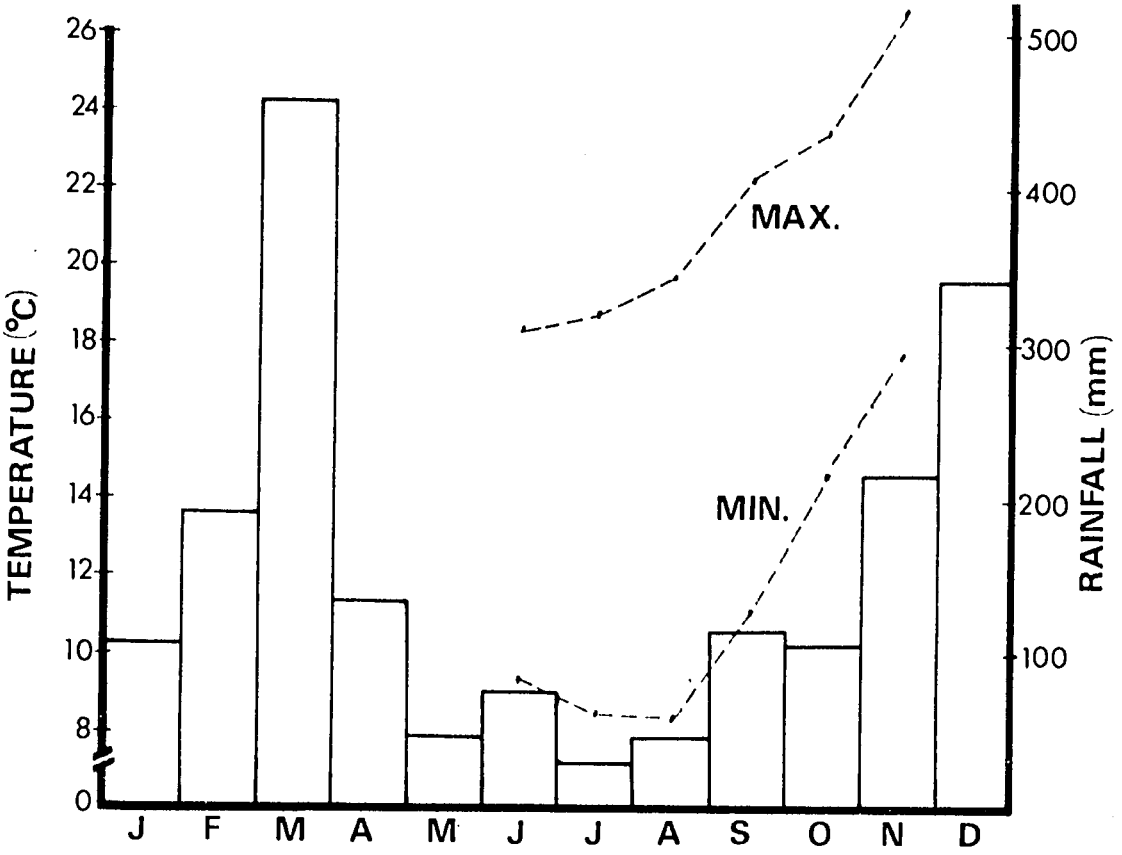

Figure 1. Monthly mean temperatures for the experimental site and rainfall for Kyogle.

approximately 0.5° C warmer from August to December. Rainfall in 1975 was somewhat above average in February and March, low from April to July, and well above average from September to December.

Dry matter yields (Fig. 2) of Weiko III were lower than those of the other three varieties ($P < 0.01$). However, Weiko III has a slower emergence rate and takes longer to develop nodules following late sowing than does Unicrop (Farrington, 1974). DM yields of Weiko III from sowings in March or early April can be expected to equal or exceed those of Unicrop. Correlations between plant population densities and DM yield were high ($r^2 = 0.64$–0.92) for the first two harvests but decreased with subsequent harvests. This appeared to be partly due to the complex branching habit of lupine which is known to be influenced by population density, growing conditions, and the length of the growing season (Greenwood *et al.*, 1975). However, the variability in the data from the last two harvests suggests that some unknown factor also influenced branch development.

IVDMD of Weiko III was considerably greater than that of the other three varieties over the first four harvests (Fig. 3). IVDMD of leaf and stem at harvest two were Unicrop, 78% and 53%; Weiko III, 77% and 78%; WBI, 71% and 65%; and WBII, 72% and 63%, respectively. This is in accord with data on lignification of stalks of the three species (Tomaszewska, 1966). The decline in IVDMD of Weiko III at harvests 5 and 6 differs from results obtained by Royal and Hughes (1975) in which Weiko III IVDMD remained above 70% as late as early September, and animal production was equivalent to that from oats (*Avena sativa*) and ryegrass (*Lolium multiflorum*). The increase in IVDMD of WBI and WBII at the last harvest may have been due to the

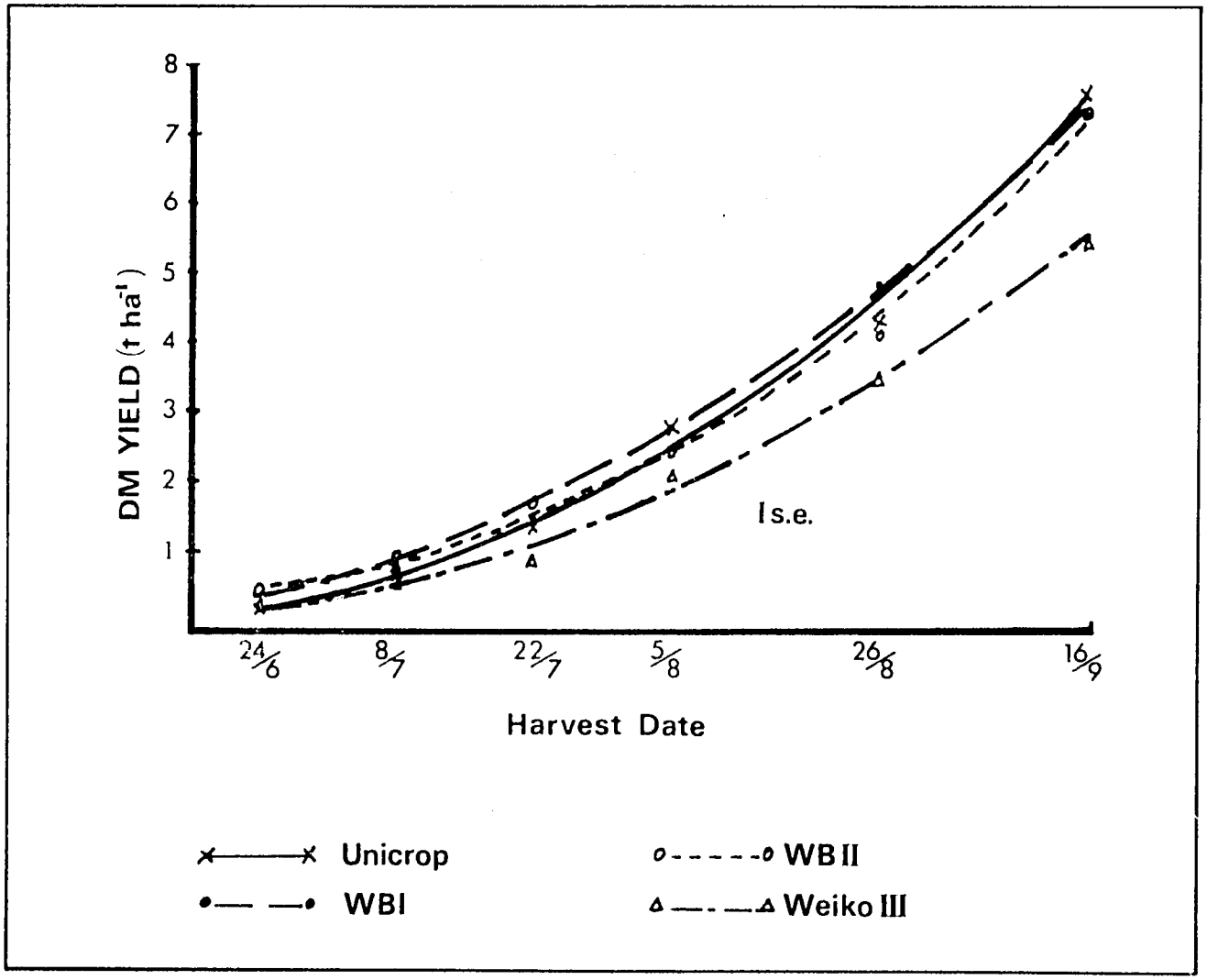

Figure 2. Growth of four lupine varieties oversown into grass pasture.

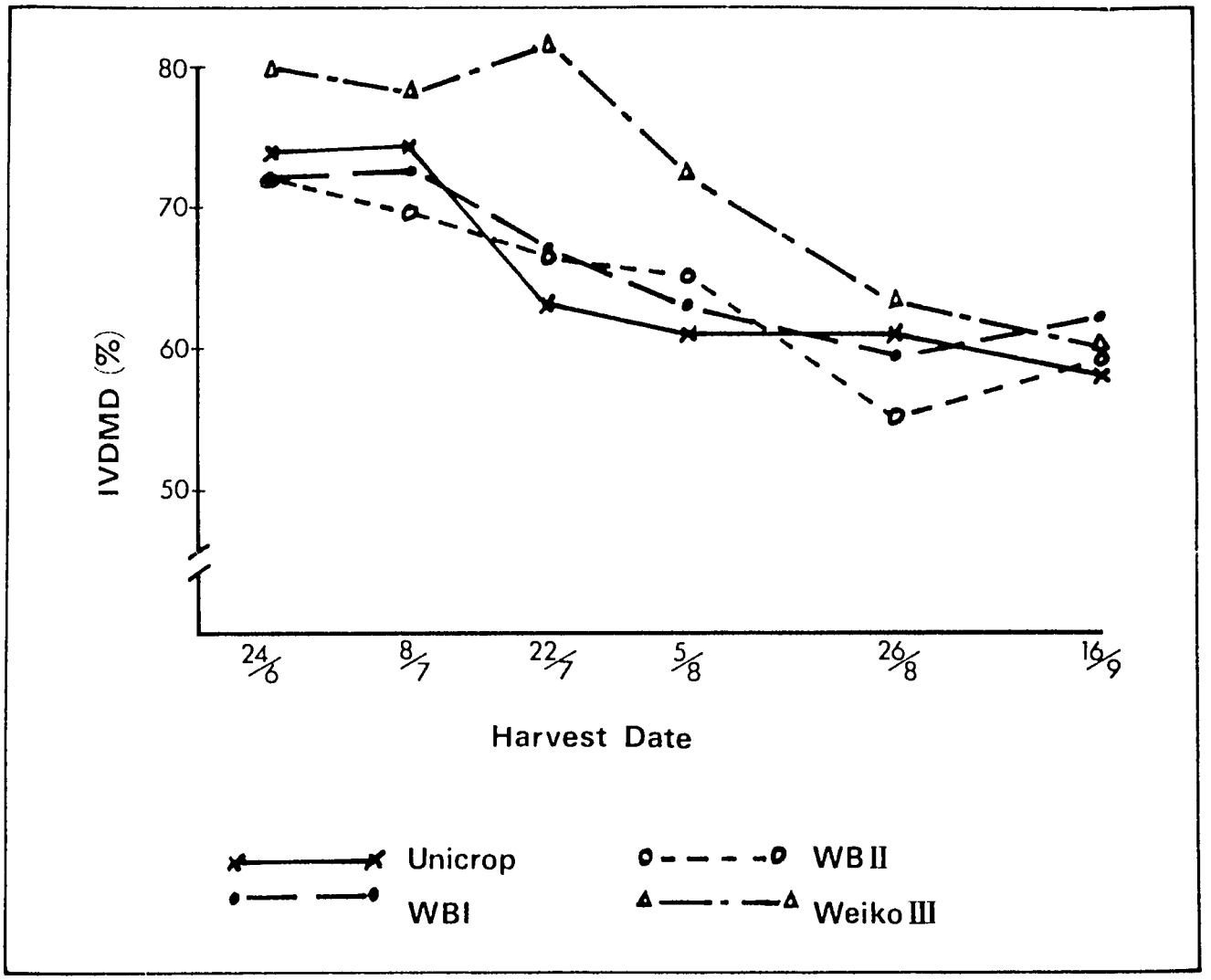

Figure 3. *In vitro* dry matter digestibility of four lupine varieties.

contribution made by developing pods and seeds (Davis and Offutt, 1975). Significant differences between these four varieties in their value as forage crops are not known at this time as there are no comparative data on utilization or animal production.

No grain yield estimates were made for Unicrop, because rats selectively harvested this variety. Grain yields of WBI (2 300 kg ha^{-1}) and WBII (2 300 kg ha^{-1}) were higher ($P < 0.01$) than those of Weiko III (800 kg ha^{-1}). Grain crude protein ($N \times 6.25$) levels were 33.7%, 34.4%, and 30.9%, respectively. Grain yields and protein levels of Weiko III were low compared to those reported elsewhere (Gladstones, 1970; Farrington, 1974). Possible reasons were the high rainfall and high winds experienced in October and November. The basal branches of Weiko III were particularly vulnerable to the effects of high winds. The regressions for plant density and grain yield were non-significant for each of the varieties, indicating that for grain production lower sowing rates can be used.

The results show that lupines have a number of attributes that make them particularly useful in hill lands in sub-tropical areas. High yields of high quality forage are produced at a time when pasture production and quality are normally low. With conventional forage crops the optimal area is difficult to determine because of variation in seasonal conditions. If excess lupines are sown for forage, then the portion not required for grazing can be left to produce grain. Grain yields are high enough to make the crop economically viable as a cash crop. As neither cultivation nor herbicides are required, both costs and detrimental effects on the environment will be minimized. The base pasture not only remains intact but responds to any nitrogen fixed by the crop.

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DISCUSSION

S. Powles (Michigan, USA). This was a very high-yielding crop in its first year and I'm not sure what the fertility level of that soil was, especially as regards the N status, but I would like to know if you have any information on the efficiency of nodulation?

Swain. There was no N used. These lupins were effectively nodulated. Superphosphate was used at about 224 kg per ha and potash at 112 kg/ha. The lupins perform very well if you get them effectively nodulated, and there has been a lot of work done with lupin Rhizobia in Australia. Adequate P and K are required, but this is a lower cost fertilizer regime than if you have to supply N. And, of course, you are producing a high-protein crop.

66.
Ironbark Ridges—Problems of Utilization

W. H. Johnston

Wagga Wagga, New South Wales, Australia

Mugga ironbark (*Eucalyptus sideroxylon*) is a dominant native tree species forming a discontinuous dry sclerophyll forest community in inland southeastern Australia. Its general distribution is shown in Fig. 1 (Hall *et al.*, 1970). The community occurs in areas receiving between 450 mm and 600 mm median annual rainfall (Beadle, 1948; Anon., 1974).

Ironbark ridges have been studied in the Temora District of southern New South Wales. Their distribution is shown in Fig. 1 (Johnston, 1975a). Their occurrence is related to geology and soils (Johnston, 1975b) which have been related to landform and erosion hazard (Crouch, 1975).

Ironbark communities occur on elevated areas of Silurian and Ordovician slates and shales. Where the sediments are overlain by more recent deposits, vegetation changes abruptly to a savannah woodland of gray box (*Euc. woollsiana*). Dwyer's Mallee gum (*Euc. dwyeri*) replaces ironbark on elevated areas of igneous or metamorphic origin.

Soils include lithosols (Um1.21) (Northcote, 1974), yellow and brown solonetzic and solodic soils (Db2.33, Dy3.42) and red podzolic soils (Dr2.21). With the exception of the lithosols, soils are duplex, having coarse to medium textured upper horizons and clay subsoil. They are stony, of variable depth, and often contain coarse gravel and sand seams

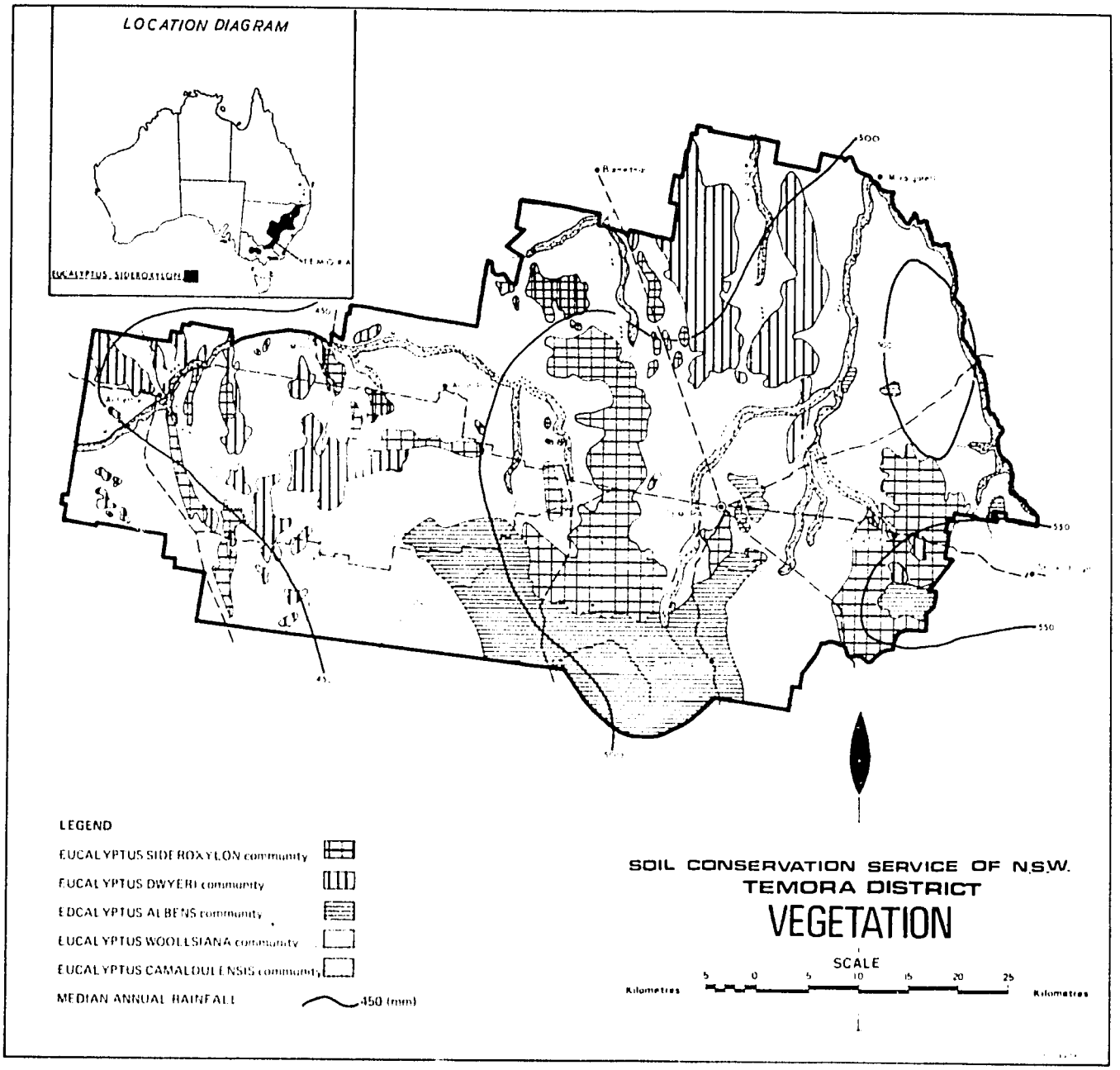

Figure 1. Vegetation—Temora District, N.S.W.

parallel to the surface. They are usually highly dispersible.

Ironbark ridges, although of low relief, are highly erodible. Under natural conditions ground flora is sparse, consequently runoff yields are high. Once cleared for agricultural production, significant erosion can occur.

A comparative study (unpub.) of an ironbark and yellow box (*Euc. melliodora*) woodlot at Wagga Wagga showed that living grass provided 9% and 25% and fallen litter 77% and 65% ground cover, respectively. Cover differences could not be attributed to soil type, bulk density, soil strength, or moisture content after rain. It is doubtful if light penetration is limiting and a phytotoxic influence on other species is suspected.

Living ground cover and length of slope have been found more important in determining erosion rates than actual slope or natural forest litter (Williams, 1972). On ironbark ridges, slopes rarely exceed five degrees but may exceed 1.5 km in length. When cleared, ground cover, including litter, declines,

runoff is concentrated to flowlines and accelerated gully, tunnel and sheet erosion results.

Climate is the main factor limiting overall productivity. The climate of the Temora and adjacent areas within the upper Murrumbidgee River catchment is essentially mediterranean (Johnston, 1975c; Edwards and Johnston, 1975). A large seasonal increase in evaporation reduces the effectiveness of summer rain.

There is slightly more rainfall during the cooler months, May to October; variability is highest during summer.

Median annual rainfall decreases from 550 mm in the east to 450 mm in the west (Fig. 1). Annual evaporation is approximately 1 340 mm. Mean temperatures range from 7° C to 23° C; extreme values of −5° C and 45° C have been recorded. The average frost-free period is 192 days (Foley, 1945).

The effect of climate on plant growth has been assessed using a monthly moisture balance and growth model (Lynch, 1976). This is shown for Temora in Table 1 together with the monthly median rainfall and percentage frequency of water surpluses which are assumed lost as runoff.

The probability of an up to four-month drought at Temora is shown in Table 2.

Greatest erosion hazard occurs when ground cover is depleted and there is a high risk of intense rain. Daily rainfall analysis for Temora (unpub.) shows 38% of January rainfall and 38% of the raindays involve falls exceeding 30 mm per day. The corresponding values for July are 5.4% and 0.5%. Therefore, land management during summer is very important.

Land use on ironback ridges includes winter cereal growing and sheep and cattle grazing. Property sizes vary from 200 to 2 000 ha. On farms smaller than 250 ha, increased soil erosion often results when an attempt is made to offset reduced earnings by increased land use. Productivity from these areas is low.

The effects of land use practices such as grazing intensity, length of crop rotations, summer fallowing, and stubble burning on erosion rates are significant.

Calculations using data given by Kohn *et al.* (1966) show that at Wagga Wagga, which is climatically similar to Temora, an increase in soil moisture storage as a result of summer fallowing will occur less frequently than one year in four. Despite this, summer fallowing is widespread. Soil loss from small plots during the fallow wheat phase of a three-year rotation is six times greater than during the first year of ley pasture and seventeen times that from the second year pasture (Anon., 1975). Loss rates

TABLE 1. Growth indices for Temora, New South Wales

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MMR	32	26	24	31	35	48	40	42	38	45	38	36
SMI*	0.2	0.2	0.2	0.4	0.5	1.0	1.0	1.0	1.0	1.0	0.5	0.2
TI	0.8	0.8	1.0	0.8	0.4	0.1	0.1	0.2	0.5	0.8	1.0	0.9
GI	0.2	0.2	0.2	0.4	0.4	0.1	0.1	0.2	0.5	0.8	0.5	0.2
% surplus	0.0	0.0	0.0	2.2	4.3	12.0	21.7	29.3	14.1	8.7	1.1	0.0
Magnitude	0	0	0	27	56	21	23	22	26	18	10	0

*Index number of 1.0 represents optimum growth conditions for cool season species.
MMR: Median monthly rainfall (mm).
SMI: Median soil moisture index.
TI: Temperature index.
GI: Growth index—most limiting value of SMI or TI.
% surplus: % occurrence of calculated runoff.
Magnitude: Relative magnitude of calculated runoff—median value.

TABLE 2. The probability of drought periods, Temora, New South Wales

No. of consecutive months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.83	0.85	0.75	0.60	0.23	0.02	0.00	0.00	0.02	0.16	0.52	0.77
2	0.73	0.65	0.51	0.16	0.02	0.00	0.00	0.00	0.02	0.14	0.45	0.63
3	0.54	0.45	0.15	0.00	0.00	0.00	0.00	0.00	0.02	0.12	0.38	0.57
4	0.37	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.35	0.41

on ironbark lands are expected to be in excess of this.

Erosion rates would be reduced if land preparation did not commence until early autumn and if stubble from the previous year were retained. By calculation from Table 2 the chance of adequate moisture for land preparation over three months commencing in March is 0.85. This compares with 0.43 for a similar period commencing in December.

A delay in cultivation may also reduce the effective stocking rates during summer as more land will be available.

Soil conservation practices on ironbark areas include banks (terraces) to control runoff, earth dams for gully control, waterways and flumes for runoff disposal, and deep ripping of hardpan and eroded areas to promote infiltration. Contour cultivation, stubble mulching, short autumn fallows, strategic grazing, conservation stocking, and pasture improvements are encouraged, and in specific circumstances low-interest loans are available for landholders to carry out their programs.

Establishment of improved grass/legume pasture species requires heavy fertilizer application. Trials (unpub.) have shown initial application rates in non-eroded situations of 30 to 40 kg P ha^{-1}. Subsequent applications of 10 kg P^{-1} each year are usually recommended, particularly on arable land. On exposed subsoil, recommended initial application rates are generally higher by a factor of 1.3 to 1.5.

Pasture species for ironbark areas must either be annuals to escape the summer drought or strongly summer dormant or drought tolerant perennials. Annual species include subterranean clover (*Trifolium subterraneum*) and Wimmera ryegrass (*Lolium rigidum*); summer dormant species include Australian commercial and Sirocco phalaris (*Phalaris tuberosa*); and drought tolerant species include Currie cocksfoot (*Dactylis glomerata*), Perennial veldt grass (*Ehrharta calycina*), African lovegrass (*Eragrostis* spp.), and Hunter River lucerne (*Medicago sativa*).

Species trials on ironbark areas (unpub.) indicate Geraldton, Daliak, and Seaton Park cultivars of subterranean clover, which mature by the end of October, are essential because of the high drought risk in November (Table 2). The growth of Wimmera ryegrass in years subsequent to sowing is variable. Annual pastures, although important in ley farming, do not provide adequate soil protection during summer and do not persist when sown on soil conservation earthworks (Johnston, 1975d). Of the perennial species, *Sirocco* phalaris was found most suitable, although under continuous heavy grazing it will not persist. The strongly drought-tolerant summer growing grass, African lovegrass, was superior to cool season grasses in two trials on ironbark areas (Johnston, 1974). In one trial it survived for six years in an area heavily grazed during summer. The grass is not commercially available in Australia.

The limiting climatic factor of the district is modified by the ironbark ridges to give a more arid microclimate. Comparative estimates (unpub.) of infiltration capacity (after Rogers, 1970) show a rapid decline between topsoil, mixed topsoil, and subsoil of a low profile bank and subsoil of the channel. Rates after 60 minutes were 50 mm hr^{-1}, 20 mm hr^{-1}, and 3 mm hr^{-1}, respectively. Low infiltration rates limit rainfall effectiveness while higher runoff results in the seed of annual species being washed down slope and contributes to a decline in persistence.

While infiltration rates are low any practice which ponds water on the surface should increase water absorption.

A comparison was made (unpub.) between contour sowing with and without trailing harrows using a cool season annual pasture mixture and a wide tine chisel seeder. The harrowed treatment resulted in a uniform soil surface, whereas without harrows the soil surface was furrowed. Gypsum was applied at rates of zero, 2 500 and 5 000 kg ha^{-1}. The first season was one of the driest on record; the second was abnormally wet. Measurements of dry matter yield and soil moisture to a depth of 10 cm were made in June, August, and October. The first and last rating correspond with the usual commencement and end of the growing season.

Soil moisture differences due to harrowing were significant only at the first rating. The use of harrows reduced mean moisture content from 13.4 to 11.5% oven dry weight. This measurement was made four days after rain, whereas the subsequent ratings were made within 24 hours of rain. The effect of gypsum was significant only at the end of the season where moisture contents of 8.5%, 9.2%, and 11.6% oven dry weight corresponded with the zero, 2 500, and 5 000 kg ha^{-1} treatments. In August, harrowing reduced yield from 1 373 kg ha^{-1} to 904 kg ha^{-1} dry matter, and in October from 4 850 kg ha^{-1} to 2 710 kg ha^{-1}.

Yield increases of 53% were found with gypsum applied at 5 000 kg ha^{-1} in both August and October.

There is no doubt that the furrowed seedbed improved moisture relations and plant growth and such a practice should be recommended on ironbark lands.

Moisture distribution in an adjacent 64 m × 25 m trial area defined three moisture zones (unpub.). A very dry zone occurred above a zone of intermediate moisture content which separated the dry zone from a lower and much wetter area. Soil profile examination in each zone showed differences were due to the presence of a gravel seam between 10 and 20 cm beneath the surface in the dry zone and close to the surface in the wet zone.

In the dry zone the gravel seam was cemented,

forming a hard impermeable layer. Mean moisture content of the soil above the seam was 5%, while below the seam, at the top of a clayey B2 horizon, it was 9% oven dry weight.

In the intermediate zone the gravel seam was discontinuous. Surface moisture content was about 12%, while subsoil moisture content increased to 35 to 40% at 40 cm depth. In one profile free water was present in a gravel aquifer.

The wet zone was characterized by an inverted moisture profile decreasing from 20-23% to 14% at 50 cm depth. A moisture content of 8% was associated with a cement sand seam 15 cm below the surface.

Unequal soil moisture distribution and concentration of lateral flow have important implications in land use and soil conservation.

In extreme situations variable moisture availability may adversely affect grain yields and result in uneven pasture growth. The presence of aquifers and gravel seams may influence the stability of conservation works and where they are close to dispersible subsoils, may promote tunnel erosion.

Deep ripping of cemented gravel seams to promote infiltration should reduce these effects.

The experimental findings reported here indicate certain routine soil conservation measures as more effective than others in maintaining stability of ironbark ridges under agricultural production. These are:

1. Graded banks to reduce length of slope and avoid runoff concentration in flowlines.
2. Deep ripping of impermeable hard pans to promote infiltration and uniform water distribution. The use of gypsum in critical areas will be of further benefit.
3. Contour cultivation to maintain surface roughness. Revegetation of disturbed, eroded, and water disposal areas requires heavy fertilizer application and judicious species selection as identified by field trials.

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67.

A 20-Year Study of Pasture Development Through Phosphate and Legume Oversowing on North Island Hill Country of New Zealand

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The Te Awa hill pasture research area is situated about 320 m above sea level on the watershed between the Pohangina and Oroua rivers, approximately 30 km north of Feilding (175°50′ E, 40°08′ S) and has a climate well suited to grassland farming. Annual rainfall over the period 1948–68 averaged 1 062 mm, ranging from 782 mm in 1963 to 1 259 mm in 1956 and was generally fairly evenly spread throughout the year; however, monthly falls varied greatly (e.g., January rainfall from 23 mm in 1954–55 to 175 mm in 1959 to 196 mm in 1961).

September and March were the driest months, with average falls of 61 and 66 mm, respectively, and December the wettest with an average of 110 mm. The wettest period was from May to August and there were occasional summer droughts.

The soil, classified as Raumai sandy loam, hill soil, is an intergrade between a yellow-grey earth and yellow-brown earth (Rykse, in press). It would be classed as a Dystrochrept (Soil Survey Staff, 1976), moderately firm on the surface with pockets of gravel showing as remnants of old river terraces. Beneath this gravel is an almost pure friable sand subsoil some hundreds of meters in depth. This soil type is typical of about 84 sq km of moderately steep hill country with slopes of 20 to 40 degrees. Most of the area is deeply and closely dissected.

The district was settled in the 1880's, and large areas of native forest were felled, burned, and sown to grass. Under the original forest, the land was reasonably stable. However, after felling, severe erosion took place. Fertility, built up over centuries of forest litter, yielded heavy production for a short period. However, lax grazing through understocking, erosion of the surface soil, and cash cropping such as seed harvesting to provide grass seed for the new burns, resulted in the spread of bracken fern (*Pteridium aquilinum* L.), manuka scrub (*Leptospermum scoparium* Forst.), toetoe (*Cortaderia fulvida* (Buchan) Zotov.), and sedges (*Carex* spp.).

By the 1920's scrub reversion was a major problem. By now stock was more plentiful and control of scrub growth by cutting and burning, surface sowing, and stock management was possible. Realization that heavy stocking was necessary to maintain clean pastures resulted in a decline in fertility and accelerated erosion as stocking rates were increased. As no fertilizer was applied, pastures deteriorated to the stage where they would support only 2 to 3 ewes/ha plus some cattle.

Seeds mixtures sown on the ash from the bush burn generally contained some ryegrass (*Lolium perenne* L.), crested dogstail (*Cynosurus cristatus* L.), cocksfoot (*Dactylis glomerata* L.), browntop (*Agrostis tenuis* Sibth.), and white clover (*Trifolium repens* L.).

Heavy stocking rates were necessary to control secondary growth, but under this management cocksfoot was nearly eaten out of the sward and the poor strains of ryegrass and white clover rapidly disappeared leaving clover-deficient pastures dominated by browntop, *Notodanthonia* spp., Yorkshire fog (*Holcus lanatus* L.), and flat weeds. Clover deficiency was also induced by smother from rank grass when it was seen that heavy stocking was causing severe erosion.

PASTURE COMPOSITION

At the commencement of the trials at Te Awa in 1948, pastures had deteriorated markedly. There was 6.2% of bare ground, 21.4% browntop, 14.1% catsear (*Hypochaeris radicata* L.), 10.7% sweet vernal (*Anthoxanthum odoratum* L.), 7.5% Chewings fescue, 7.2% Yorkshire fog, 6.8% ryegrass, 6.5% *Notodanthonia* spp., 5.4% crested dogstail, 1.5% cocksfoot, 2.4% other grasses, 3.8% suckling clover (*Trifolium dubium* Sibth.), 1.5% white clover, and 4.7% other species on a ground cover basis (Suckling 1950a). This turf was not strong or dense enough to prevent soil loss by runoff or to support animals in a thrifty condition. Consequently, research was considered necessary to determine methods of pasture improvement. It is still an open question as to whether pasture improvement or reforestation offers the best prospects for soil conservation. There is need for more information on the potentialities for improvement of hill pastures from both a farming and soil conservation point of view. Research at Te Awa was intended to supply some of this information. In the early stages, emphasis was on improving

the productivity of pastures. Soil conservation practices which could be developed consistent with increased production would be more beneficial and more readily adopted by the farmer, the thinking held.

PASTURE IMPROVEMENT AND THE NEED FOR CLOVERS

In New Zealand, grasses and clovers grow well and animals may be grazed on pastures throughout the year. Our farming pattern, consisting of the animals harvesting feed for themselves all the year round, may rightly be considered to be the cheapest system in the world for animal production. Research at Grasslands Division, Palmerston North, New Zealand, has shown that fertility building depends on our ability to grow vigorous leafy clovers which are grazed by stock to produce large quantities of nitrogen which is distributed in their dung and urine over the pasture, thus encouraging the grass component of the sward to produce greater quantities of herbage than would otherwise have been produced by grass or clover alone (Sears and Newbold, 1942). Sears *et al.*, (1948) reported a 33% increase in pasture production from dung and urine returned to the pasture. They also showed that a high producing grass and clover sward yielding 30 000 kg/ha of dry matter requires for its growth nitrogen equivalent to that in 3 000 kg of sulphate of ammonia per ha, phosphate equivalent to that in 800 kg of superphosphate per ha, potash equivalent to 1 800 kg of 30% potash salts per ha, and lime equivalent to that in 400 kg of carbonate of lime per ha.

Huia white clover growing in a high-producing mixed grassland sward extracts from the air per ha, per year, nitrogen equal to that contained in 2 000 kg of sulphate of ammonia per ha. In New Zealand we feel this nitrogen cycle is vital to fertility building.

OVERSOWING

A noticeable feature of New Zealand hill pastures is the lack of productive clovers, and since it has been demonstrated that clovers can largely make good any nitrogen deficiency on our hill pastures, the research area was oversown by hand with improved strains of clover as the initial step. The seed mixture used was Certified NZ perennial ryegrass (*Lolium perenne* L.) 22 kg/ha, crested dogstail (*Cynosurus cristatus* L.) 6.6 kg/ha, Montgomery red clover (*Trifolium pratense* L.) 4.4 kg/ha, broad red clover 4.4 kg/ha, certified white clover (*Trifolium repens* L.) 4.4 kg/ha, Mt Barker subterranean clover (*Trifolium subterraneum* L.) 2.2 kg/ha, Tallarook subterranean clover 2.2 kg/ha, and 1.1 kg lotus major (*Lotus pedunculatus* Cav.)/ha. Sowing was completed by April, 1948. Establishment counts (Table 1) determined the percentage establishment of viable seed sown, two and four months after sowing.

TABLE 1. Establishment counts of clover seedlings: % of viable seed sown

Length of time after sowing	Red clover (%)	White clover (%)	Subterranean clover (%)	Lotus major (%)
2 months	3.2	3.5	9.4	0.5
4 months	1.6	1.7	13.1	0.4

These low establishment percentages prompted experiments to determine optimum conditions and time for oversowing. On most hill country in New Zealand, the steep and often deeply-gullied hills preclude any possibility of preparing a seed bed for the introduction of improved species and strains of grass and clover seed except by the use of large flocks of sheep and/or herds of cattle which break the turf with their hooves when driven around a paddock.

Trials were laid down at sites selected to cover a wide range of soil types and climatic conditions to determine the best month for surface sowing. A total of 42 ha was sown experimentally with clovers and grasses, and in most cases the area sown was topdressed with superphosphate at 250 kg/ha. Sowings were made at six different times of the year. These trials showed that almost without exception early autumn sowings in March were superior to sowings in April or May, or in the spring months of August, September, and October (Table 2). In general, it was apparent that sowing should take place when there was an assured continuity of moisture supply (Suckling, 1950b). In areas where rainfall was more evenly spread over the summer spring sowings were as good as autumn sowings.

The influence of management on the establishment of legume species was investigated in small plot studies at Te Awa in 1951. Close continuous grazing to the 1 to 3 cm level before sowing resulted in a significantly higher percentage establishment than did lax grazing (5 to 10 cm). Applications of 250 kg/ha superphosphate at sowing did not improve early establishment.

There was no difference in the establishment of red clover, subterranean clover, and lotus major under the three post-sowing treatments of continuous grazing, short spelling, and long spelling but white clover establishment was reduced by long spells (4–6 weeks) between grazing.

There were indications that long spelling prior to sowing did not reduce greatly the establishment of subterranean clover, but when grazing did take place, losses were recorded due to defoliation of the seedlings below the crown.

White clover and red clover established significantly better on turf cut to 1–2 cm before sowing than on 5 to 10 cm-long pasture.

TABLE 2. Percentage establishment of viable seed sown

Month of sowing	Red Clover		White Clover		Lotus spp.		Strawberry Clover (*T. fragiferum*)		Subterranean Clover	
	2 months	12 months	2 months	12 months	2 months	12 months	2 months	12 months	2 months	12 months
March	30	10	27	—	15	Trace	9	Trace	83	40
April	25	7	22	—	8	Trace	3	Trace	47	17
May	3	6	5	—	1	0	3	Trace	2	4
August	6	5	11	—	3	Trace	1	Trace	4	6
September	9	6	7	—	1	0	0.4	Trace	10	7
October	14	6	12	—	2	Trace	0.6	Trace	7	12
Mean	15	7	14	*	5	Trace	3	Trace	26	14

*It was not possible to distinguish volunteer clover from oversown clover 12 months from sowing.

Legume seedlings were attacked seriously by insects and slugs at the radicle emergence stage. Birds played an insignificant part in the destruction of legume seeds and seedlings; seedling losses were more severe under bird-proof cages than on unprotected sites (Suckling, 1951, 1952).

Establishment counts were made to assess the results from the large-scale sowings at Te Awa (Suckling, 1954). These showed establishment rates of 3.2% for red clover, 3.5% for white clover, 9.4% for subterranean clover, and 0.5% for lotus major. Strawberry clover (*Trifolium fragiferum*) sown on part of the area failed to establish.

During a five-year field trial at Te Awa where the effects of superphosphate and surface sowing with clovers on hill pastures were measured, clover establishment was also recorded in permanent quadrats. Shortly after sowing, 30.5% of red clover had established, 41.5% of white clover, 22% of subterranean clover, and 2% of lotus major. After another month the figures reduced to 26% red clover, 22% white clover, and 16% subterranean clover, but lotus increased to 4%. A final measurement ten months after sowing revealed that 17% of red clover, 2% of subterranean clover, and 1% of lotus major had established. It was not possible at this stage to identify sown plants of white clover. The conclusion was that losses occurred through grass smother from topdressed pasture (Suckling, 1959) as well as from insect depredations.

In a more recent study comparing establishment rates of Huia and Pitau white clover sown at the rate of 6.7 kg of seed/ha, an average of 9.6% of the seed sown became established (Suckling, 1976).

NATURAL RESEEDING

Because of the high costs involved in oversowing hill country, seed rates of clovers for oversowing programs are generally lower than those used when sowing prepared seed beds and are often less than 1 kg/ha for the three main clovers. The proportion of seeds which develop to established plants is generally much lower in a sward than on cultivated ground, hence even with favorable conditions for oversowing the resultant clover stand is likely to be sparse (Table 2). An improvement of the clover stand can be achieved relatively easily by allowing plants which are already established to act both as a source of seed and as a distributing agency. Trials at Te Awa determined the optimum date for resting pastures for reseeding clovers and measurements were taken of the results by extracting buried seed from the soil following these summer spells (Hyde and Suckling, 1952). Shutting a paddock in mid-to-late December after the bulk of spring grass production had been consumed resulted in a predominantly clover aftermath with heavy seed setting of the clover plants. Also, it took 18 days from floral initiation to seed maturity for most of the clover species, hence the period of rest could be relatively short and not disrupt farm management programs.

More than 200 kg/ha of buried clover seed remained in the top 5 cm of soil in the following winter after the summer rest which allowed the clover to reseed. Samples of sheep and cattle dung after grazing of the spelled paddock yielded a mean figure of 7 700 mixed clover seed per kg of dung. This seed was mainly in the hard condition and was distributed around the farm by the animals. Suckling (1952) found only 2% germination in hand-harvested white clover which was not subjected to any scarification during cleaning and harvesting, the remainder being hard seed. When this seed was fed to sheep in capsules, 30% of a sample of impermeable seed was recovered, as opposed to 3% of a sample of scarified commercial seed.

Thus under New Zealand conditions, it is practicable to graze areas of clover which are in the ripe head stage with large flocks of sheep which can then be turned out onto clover-deficient hill country. The natural impermeable condition of this seed is of significance not only in regard to survival

in the passage through the animal, but also because of its intermittent germination spread over a long period.

Striking examples of the effectiveness of delayed germination in ensuring survival of clover have been noted on hill country in old stands of subterranean clover. Successive lots of seedlings emerge during summer and autumn, only to be destroyed by subsequent periods of drought. Seedlings emerging later when there is a continuity of moisture supply persist and ensure a satisfactory stand. In difficult and droughty areas, reseeding clovers in this manner, by building a large reservoir of hard seed in the soil, could result in the establishment of persistent stands of clover. Perennial clovers, when grown under adverse conditions not normally suited to their growth and survival, can be treated as annuals and reseeded frequently until a reservoir of hard seed is built up.

TOPDRESSING

The natural phosphate deficiency of New Zealand hill country is one of the most important factors limiting pasture production. Insufficient phosphate largely caused the legume species to disappear from the pastures sown on the bush burn. In turn, ryegrass and other high fertility grass species also disappeared.

Although there is a definite need for phosphate on most of our hill country, disappointing results from topdressing have occurred frequently. The point to be stressed is that applications of phosphate on hill pastures are virtually wasted unless clovers are present.

The requirement for lime to reduce the acidity of hill country and thus enable better grasses and clovers to grow has also been investigated. To cause an appreciable change in pH, large quantities of lime would be necessary, causing application problems. At Te Awa pH ranged from 5.1 to 6.6 with a mean of about 5.6. At this level, clovers may be grown successfully when phosphate is applied (McNeur, 1953). Because of the cost factor no liming was done. Topdressing trials were conducted over the period 1955–59 at Te Awa on sloping hillside which had been fenced to exclude stock. Pasture production was measured by mowing. Applied phosphorus increased yield, and there was no sulphur effect. Potassium applied alone reduced yield, but the application of potassium together with superphosphate increased yield above that of superphosphate alone. There was no response to lime or molybdenum (Suckling, 1975).

Shortly after the oversowing was completed at Te Awa, sown areas were topdressed with 250 kg of superphosphate per ha. Up to 1958 the area was topdressed annually in autumn with the same quantity of fertilizer, making a total of 2 500 kg of superphosphate per ha. In 1959 most of the paddocks received a dressing of 750 kg/ha in one application coinciding with a change in program to fertilizer rate and stocking rate trials. Only two paddocks received the normal 250 kg/ha dressing at this time. In the remaining nine years 250 kg of superphosphate per ha were applied by aircraft, so that the major part of the area had then received 5 500 kg of superphosphate per ha and two paddocks 5 000 kg/ha.

EFFECT OF OVERSOWING AND TOPDRESSING ON PASTURE PRODUCTION

When the trials began in 1949, browntop was dominant on the area with danthonia on the dry knolls and faces, a small scattering of ryegrass, cocksfoot, crested dogstail, Chewings fescue, *Poa pratensis*, sweet vernal, hairgrass (*Vulpia bromoides* (L). S. F. Gray), *Poa annua* L., *Poa trivialis* L., Yorkshire fog, paspalum (*Paspalum dilatatum* Poir.), flat weeds, yarrow (*Achillea millefolium* L.), piripiri (*Acaena anserinifolia* (Forst.) Druce), toetoe, sedges, rushes, manuka, bracken and water fern (*Histiopteris incisa* (Thumb.) J. Smith), and a very thin sprinkling of white and suckling clover. The shady faces were more liable to scrub and fern invasion and were generally dominated by thick mats of moss. On the steep parts there was much *Gunnera* spp., *Nertera depressa* Banks + Sol. ex Gaertn., and *N. setulosa* Hook.f., remnants of the native forest flora.

The most outstanding features of the change which took place over the 20 years between 1948 and 1969 was that ryegrass increased markedly while Yorkshire fog, browntop, and sweet vernal decreased considerably (Table 3). White clover increased more than five-fold and subterranean clover and lotus major also increased. Catsear and other flat weeds decreased as the oversown species increased. It was noteworthy that the relatively high-producing pastures after 20 years of improvement were far from being pure stands of ryegrass and white clover, such as one would find on fertile flat land.

For measurement of pasture production, frame enclosures were placed on the area and the herbage grown within them was cut monthly, weighed, and sampled for dry matter (DM) yield, botanical composition, and protein analyses. Fig. 1 shows a comparison between improved and unimproved hillside production over the first seven years of the trial, while control paddocks were still maintained. The improved pastures produced an average of 17 615 kg DM/ha while the unimproved pastures produced 11 288 kg DM/ha. This showed a 56% increase in overall pasture production as a return for the input of one sowing of clover seed and annual dressings of superphosphate at 250 kg/ha, or a total of 3 500 kg of superphosphate per ha.

TABLE 3. Percentage botanical composition of hillside pasture in 1948 before oversowing and topdressing and in 1968 after 20 years of improvement

Year	Ryegrass *Lolium perenne* L.	Cocksfoot *Dactylis glomerata* L.	Crested Dogstail *Cynosurus cristatus* L.	Yorkshire Fog *Holcus lanatus* L.	Browntop *Agrostis tenuis* Sibth.	Sweet Vernal *Anthoxanthum odoratum* L.	*Danthonia* spp. *Notodanthonia* spp.	Other grasses	White Clover *Trifolium repens* L.	Subterranean Clover *Trifolium subterraneum* L.	Lotus Major *Lotus pedunculatus* Cav.	Suckling Clover *Trifolium dubium* Sibth.	Catsear *Hypochaeris radicata* L.	Other species	Bare ground
1948	4	2	3	8	22	9	7	5	4	0	0	2	15	4	11
1968	33	1	2	4	15	4	1	5	22	8	3	1	0	1	0

Production over the remaining period of the trial averaged 11 823 kg DM/ha on the hillsides, and 18 319 kg DM/ha on the small flat area of hilltops, where dung and urine from stock were largely deposited. Pasture production varied greatly from year to year. Fluctuation in seasonal and annual production recorded at Te Awa shows that farmers on unplowable hill country face special problems in deciding the optimum stocking rates for utilization of their pastures. When ample supplementary feed is available the problem is less difficult. However, many hill farms have little or no land suitable for hay or silage conservation and most is too steep to be cultivated for cropping. With differences in pasture production as great as 30 % between years, it is obvious that the farmer without supplements

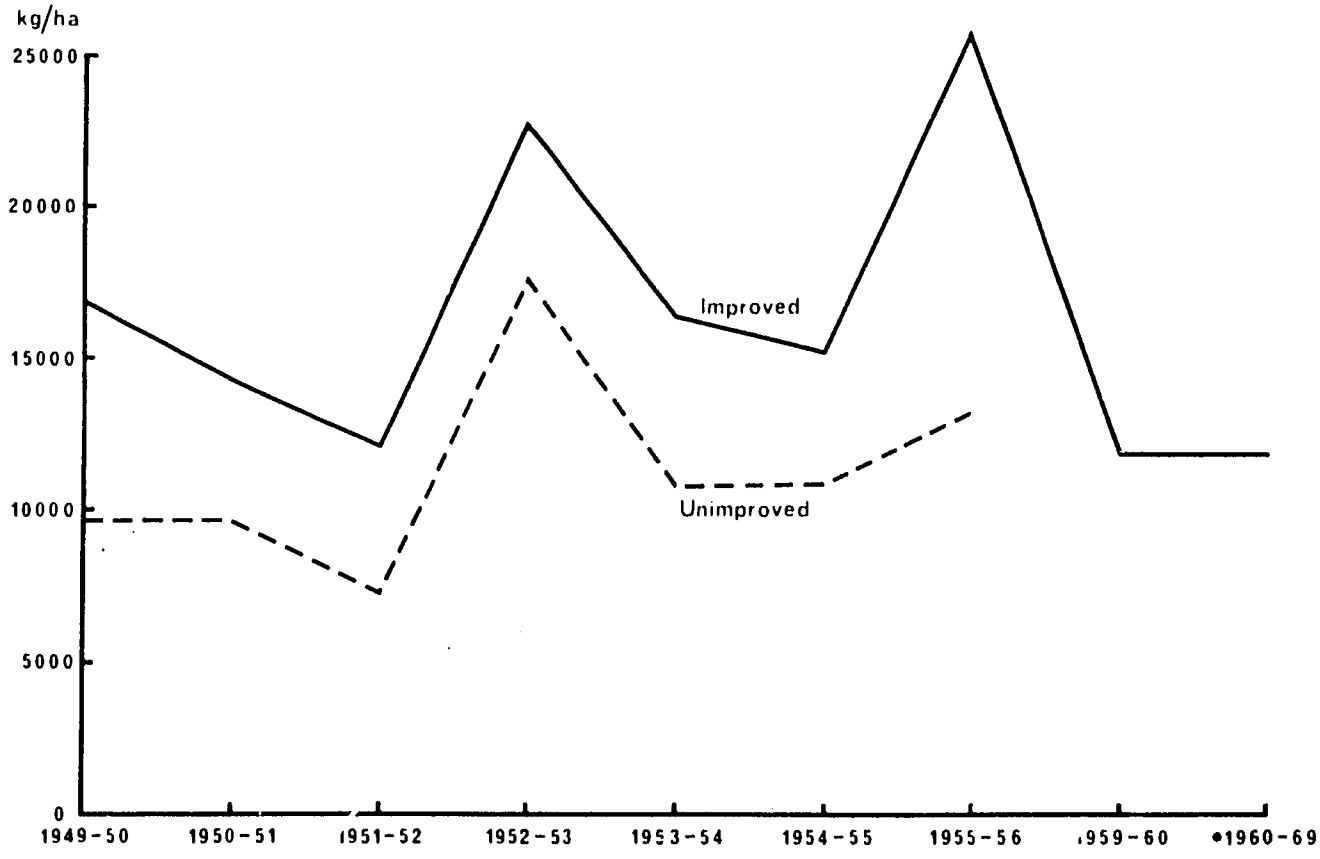


Figure 1. Comparison of improved and unimproved hillside production, 1948-56. The graph is extended for the improved pasture giving a mean for 1960-69. Control paddocks became invaded with clovers and were no longer a valid comparison.

The Te Awa research area (center) as seen by air. In the background is the Ruahine Range and State Forest reserve.

must stock for poor years rather than the good if he wishes to maintain good stock thrift and high animal production.

On the heavily stocked paddocks at Te Awa the 1961–62 and 1962–63 seasons were disastrous, pasture production being only about two-thirds of average. Lambing percentage dropped to 70 on the heavily stocked paddocks; wool yield and animal thrift suffered accordingly.

With incorporation of high-producing strains of clover and the application of phosphates a greater seasonal spread of production resulted. This not only effectively shortened the lean winter period but also extended the growth period into summer.

STOCKING RATE

On paddocks which had received no improvement by oversowing or topdressing, stocking rates increased from 3.7 ewes/ha over three years to 7.4 ewes/ha. This was entirely due to more efficient pasture management and utilization made possible by subdivision. Over the same period the carrying capacity of the improved pastures rose from 3.7 to 13.6 ewes/ha, plus cattle. On the stocking rate trials, when sheep were carried at rates increasing from 7.4 ewes/ha to 17.3/ha with varying rates of cattle in addition, the average carrying capacity in ewe equivalents was 14.5 ewes/ha at all three of the lower sheep stocking rates while at the higher rate of 16.1 ewes/ha very little cattle grazing was done and then only on sunny aspects. (The trials were carried out using standard measurements, i.e., ewes per acre etc. These stocking rate figures are a direct conversion to ewes/ha, hence they are reported to one decimal.)

EWE AND LAMB WEIGHTS ON IMPROVED AND UNIMPROVED PASTURES

Between 1948 and 1957, comparisons were made between oversown and topdressed pastures and those which received no seed or fertilizer. Sheep weights recorded in Fig. 2 represent annual average live weight of the ewes and the stocking rate is shown for each year. In 1948 all ewes were 18 months old and these, with replacements, were carried through to 6 years of age when they were replaced with a new flock of 18-month-olds. On improved pastures ewe live weights were superior to those grazed on unimproved pastures except in the first year when both groups were at the same stocking rate of 3.7/ha. There was a gradual increase in stocking rate from 3.7/ha to 13.6/ha on the improved pasture while on the unimproved pasture there was a smaller increase from 3.7 to 7.4/ha.

The airplane makes possible the oversowing and topdressing of hill country, however steep. In 1972–74 nearly 2.6 million MT of superphosphate were [illegible]. With the current economic situation, this amount reduced to 1.7 million MT in 1974–[illegible]. In addition, [illegible] MT of herbage seeds are [illegible] on unplowable hill country each year.

[illegible] the stock. Each [illegible] weight between improved and unimproved paddocks. The [illegible] that except for the first and eighth weeks, [illegible] superior on the improved pastures. The

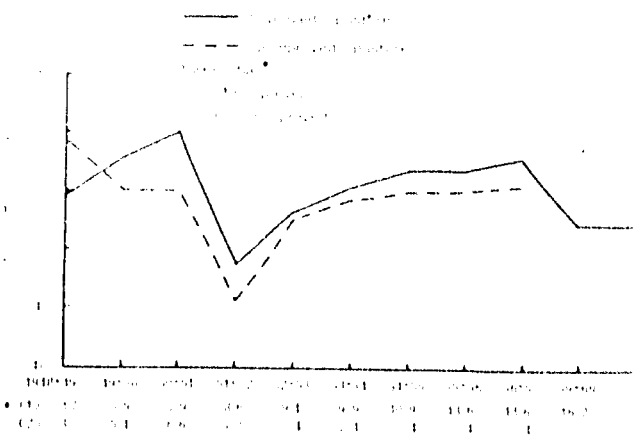


Figure 2. Mean sheep weights on improved and unimproved hill pastures for 1948–57, also showing a mean for 1959–69

most interesting [illegible] the daily gain in lamb weights continued to increase up to 1955 when stocking rates reached 13.6 ewes/ha. When ewe stocking was further increased to 16.2 over the period 1958–68 the daily gain dropped below 0.4 kg/day. Even on the unimproved paddocks with full utilization and stocked at 7.4/ha, lambs earned a comparable amount each day to those on the improved pasture.

Fig. 4 shows a comparison between an improved hill pasture yielding 20,570 kg DM/ha per year and an unimproved hillside pasture yielding 12,580 kg DM/ha. The requirements in kg DM/ha per day of 12.4 ewes, 7.4 ewes, and 7.4 ewes plus 0.3 beef cows are shown along with the appropriate lambing, calving, and weaning dates. Clearly the improved pastures could carry 12.4 ewes/ha over most of the year except for June and July, while the unimproved pasture could not support 7.4 ewes/ha in winter and summer. The most interesting feature is the obvious spread of season shown by the improved pastures. Growth started much earlier in spring and continued longer into the summer than did the growth of the control paddocks.

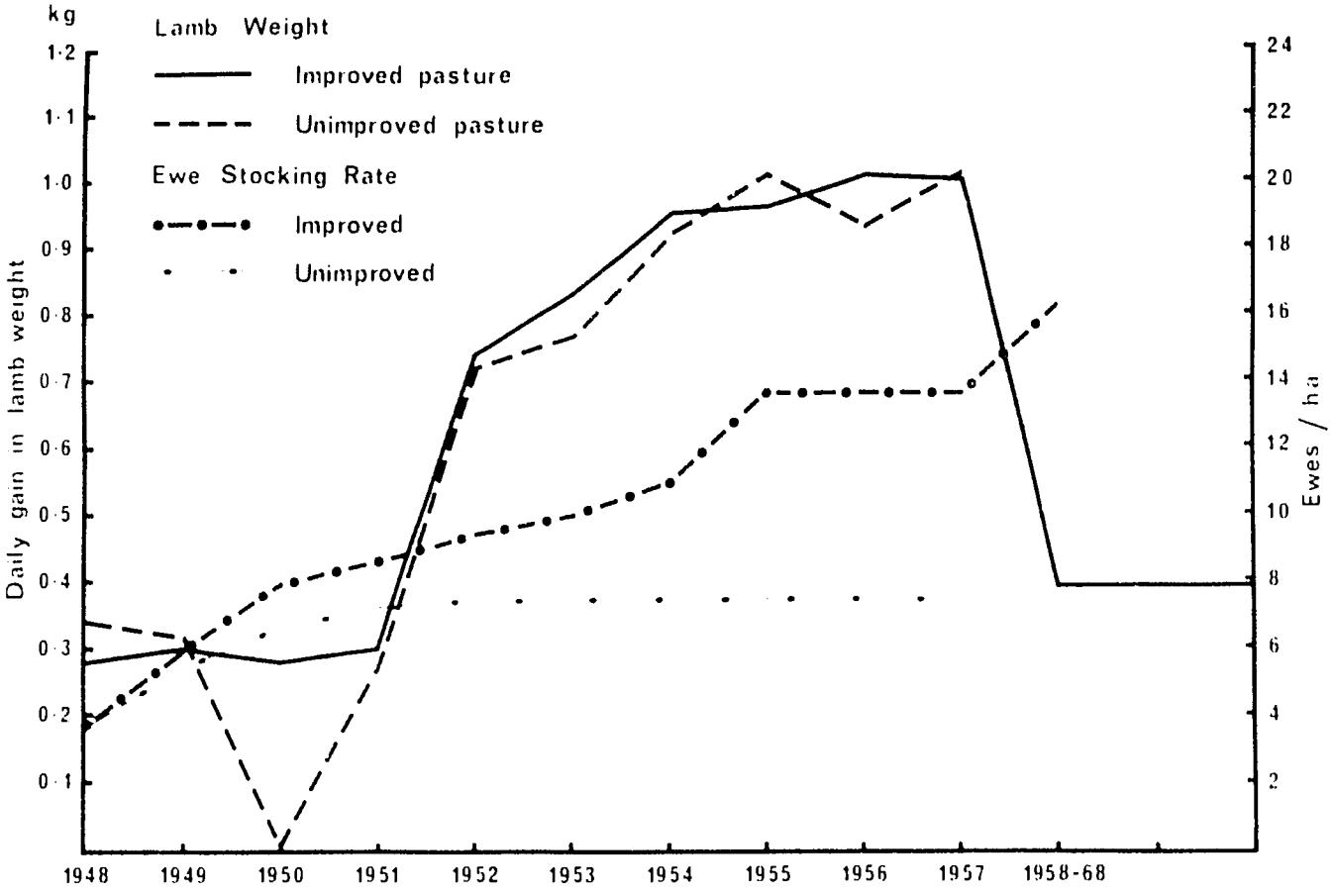


Figure 3. Daily gain in lamb weight on improved and unimproved hill pasture. Ewe stocking rates are also shown.

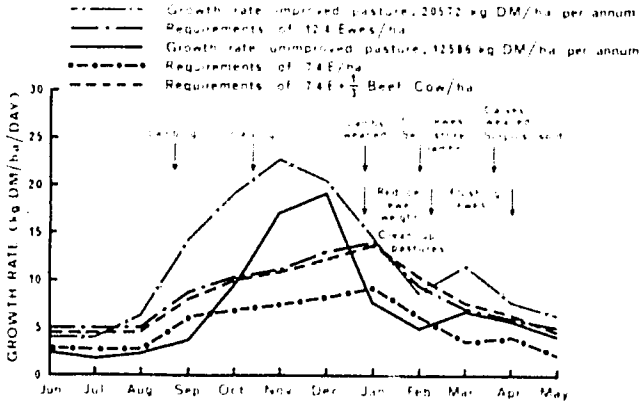


Figure 4. Improved pasture yielding 20572 kg/ha/annum compared with unimproved hill pasture yielding 12586 kg/ha/annum. Estimated ewe requirements are shown for 7.4 and 12.4 ewes/ha.

NORTH AND SOUTH ASPECTS

Varying proportions of the total area of hill farms consist of north- and south-facing slopes. On southern slopes the sun does not reach considerable portions of the area for long periods during winter. This direct lack of sunshine results in marked changes in soil temperature. An average difference of 2.1° C was recorded at 10 cm depth between northern and southern slopes on sites approximately 100 m apart on either side of a ridge running east and west. There is a much greater difference in surface soil temperature. In the North Island one finds most hill farmers have problems with pasture improvement projects on shady faces. The grazing animal tends to congregate on the warm sunny faces and to neglect almost completely the shady ones. As a result pastures on the north aspects tend to be overgrazed, while the southern aspects become rank, mossy, and unpalatable. This neglected condition encourages scrub, fern, and secondary growth. The one answer to this problem is to fence the aspects separately.

At Te Awa experiments were carried out to determine the production and carrying capacity of north and south aspects over a ten-year period (Fig. 5). Mean annual production from north aspects was 12817 kg DM/ha against 9688 kg DM/ha from south faces. Winter production for the months of June, July, and August was 940 kg DM/ha or 7.3% of

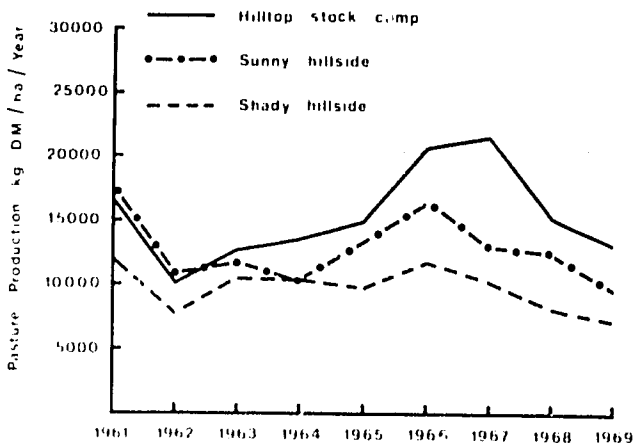


Figure 5. Mean annual production in kg DM/ha/year are shown for hilltop stock camps, sunny hillside, and shady hillside for 1961-69.

annual production on the north face and only 440 kg DM/ha or 4.5% on the shady south face. This difference in production meant that improved sunny slopes were capable of carrying 12.4-13.6 ewes/ha all the year round, whereas the south faces carried 10 ewes/ha with comparable thrift. Over the period 1959-69 mean annual production was highest on the stock camps (15 350 kg DM/ha). There were decided advantages with fencing off north from south faces as even in dry summers the shady faces seldom dried out, whereas the sunny faces frequently suffered severe drought.

STOCK MANAGEMENT

Early in the trials an experiment compared the effects of set stocking with those of rotational grazing on the general thrift of sheep and pasture (Suckling, 1959). This six-year trial showed that the heaviest ewes were produced from the heavily set-stocked paddocks (13.6/ha) which had been oversown and topdressed. Those under rotational grazing were lighter. In general, rotational grazing on a regular shift basis throughout the year resulted in a detrimental effect at lambing time on lamb weight, lambing percentage, wool weight, and general thrift. By comparison, heavy set stocking with no movement of stock produced satisfactory lambs, a good wool weight, and healthy stock. A feature of rotational grazing was the ease of shifting stock from paddock to paddock once the habit had been formed, particularly when sheep were dry. The period from lambing to weaning, however, presented some problems as rotationally grazed ewes became so accustomed to shifts that they were in a state of constant unrest and moved at the slightest disturbance. This was of consequence when the lambs were new-born and unable to travel; when ewes were left to drift through to the next paddock, sleeping or new-born and weak twins were unable to follow. Mis-mothering was a constant worry with rotationally-grazed sheep, and resulted in lower lambing percentages than when ewes were set stocked.

Under rotational grazing there was also an increase in footrot above that experienced in the set-stocked paddocks. This may have been due to an increase in scald (interdigital dermatitis) because of the longer grass.

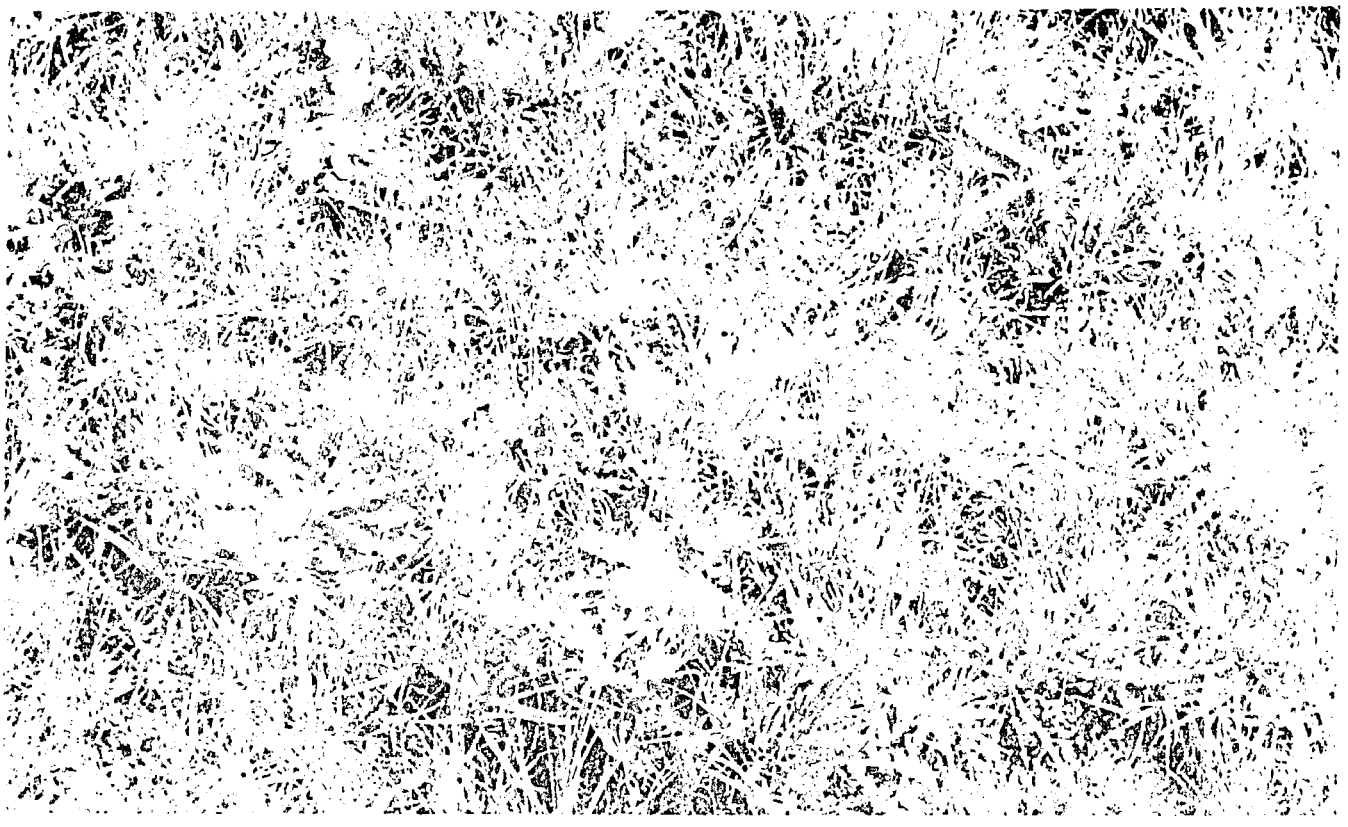
One of the main reasons for the failure of rotationally grazed pastures on hill country to support stock satisfactorily was the suppression of grass tillers due to the management system. Pastures grow quickly during spring and autumn with the result that shading at the base of grass plants reduces tillering under rotational grazing. In summer and winter, during periods of little growth, pastures open up and fail to respond between grazings. By contrast set-stocked areas are more uniformly grazed, usually at a fairly low level, which promotes maximum tillering and a large number of leaves per unit area. Under set stocking on improved pastures there was an average of 35 480 tillers/m^2, whereas under rotational grazing there were 20 410. Other figures taken from lowland dairy farms as a comparison showed an average of 7 780 tillers/sq m (Mitchell and Glenday, 1958).

Another observation with rotational grazing was fouling of pasture during wet weather, caused by restless sheep moving when disturbed and when being shifted. A large proportion of pasture was trampled down and rendered unfit for consumption.

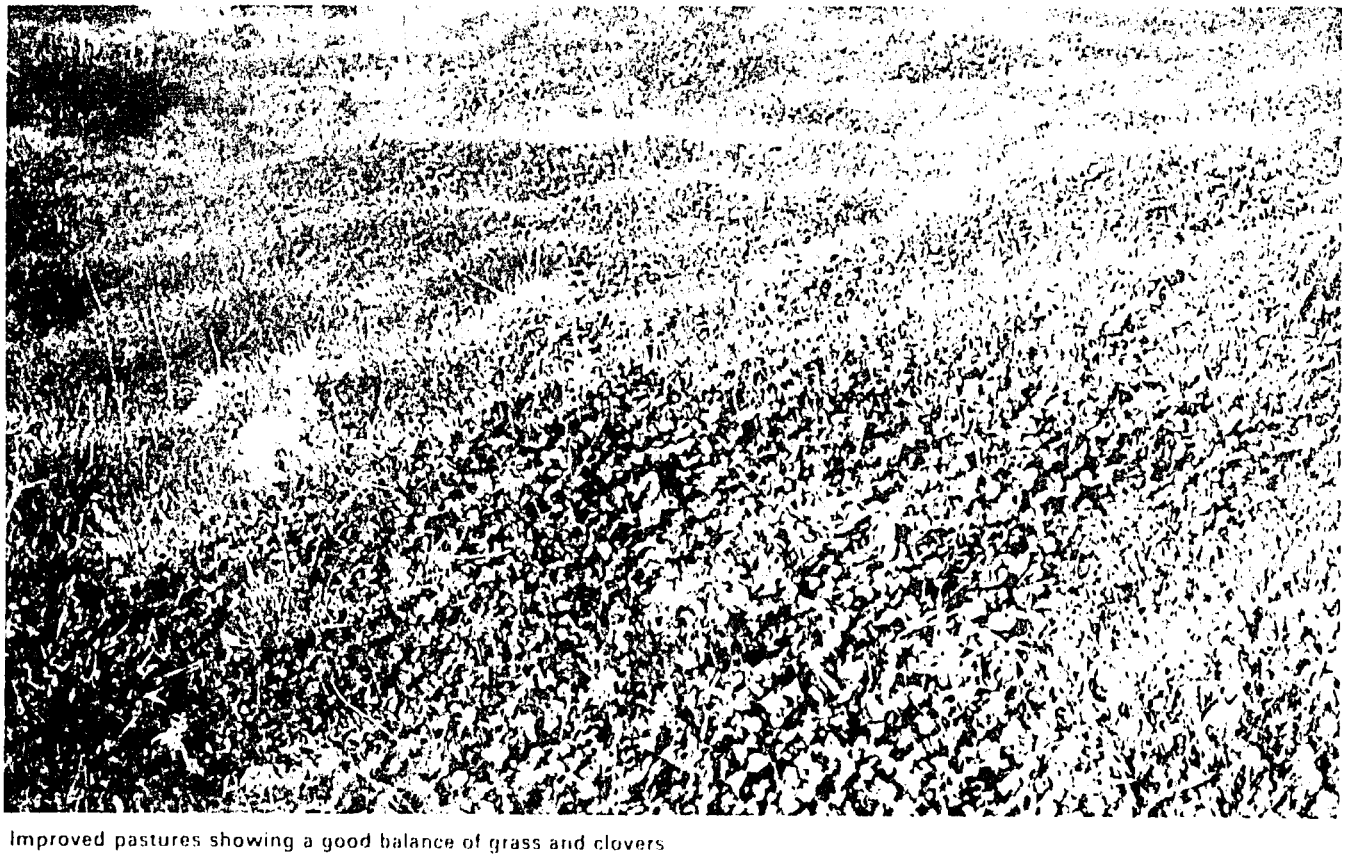
Set stocking, while appearing to be the most satisfactory management system for hill country stock, has weaknesses from a stock and pasture viewpoint. Ewes become too fat at certain times of the year for best husbandry practice, which increases incidence of bearing trouble (vaginal eversion) (Suckling, 1959).

When pasture growth is not fitted to animal requirements, ewes are also subject to pregnancy toxemia and milk fever. Obviously, the animals under this system were subjected to feed shortages and surpluses. Thus, there were no feed reserves for summer drought or for winter shortages. It was apparent that a compromise system must be sought to combine the best of both systems. This resulted in the conclusion that the farm should be subdivided into a satisfactory number of paddocks to enable flexibility in stock management (preferably 16-20 paddocks).

After weaning of lambs, ewes should be toned down to enable flushing before tupping. Flushing should then commence about three weeks before the rams are put out and continued for about a month after (Wallace, 1953). Pastures for this purpose must be conserved by shutting improved pastures during the summer, preferably as late in summer as possible.



Typical unimproved hill pasture— open, weedy and deficient in legumes



Improved pastures showing a good balance of grass and clovers

The practice of spelling shady country has proved satisfactory at Te Awa because these faces do not dry out to the same extent as sunny faces. The period between tupping and lambing presents few problems, as ewes may be grazed hard on a rotational basis without harm to either pasture or ewe, while shutting up some paddocks for winter feed.

Experience showed that ewes should be set stocked before growth ceased (which was usually about mid May) and remain spread out until weaning in December or January.

HILL PASTURE BEHAVIOR UNDER DIFFERENT STOCKING RATES

In the course of the first ten years of the previously described trials, pasture improvement was so rapid that stocking rates were increased from 3.7 to 13.6 ewes/ha plus some cattle to control surplus spring growth. A trial was decided on to determine pasture and animal behavior under different stocking rates, on pasture which had been improved to the standard required to feed adequately 13.6 ewes/ha, and also to gain further knowledge of the precise function of cattle on hill country.

The trial was started with stocking rates of 7.4, 10.0, 12.4, and 16.1 ewes/ha, with and without cattle. To overcome possible fertility differences between paddocks two heavy dressings of superphosphate were applied in 1959 and 1960. In these two years 750 kg/ha dressings were made and for the remaining eight years 250 kg of superphosphate per ha was applied each year.

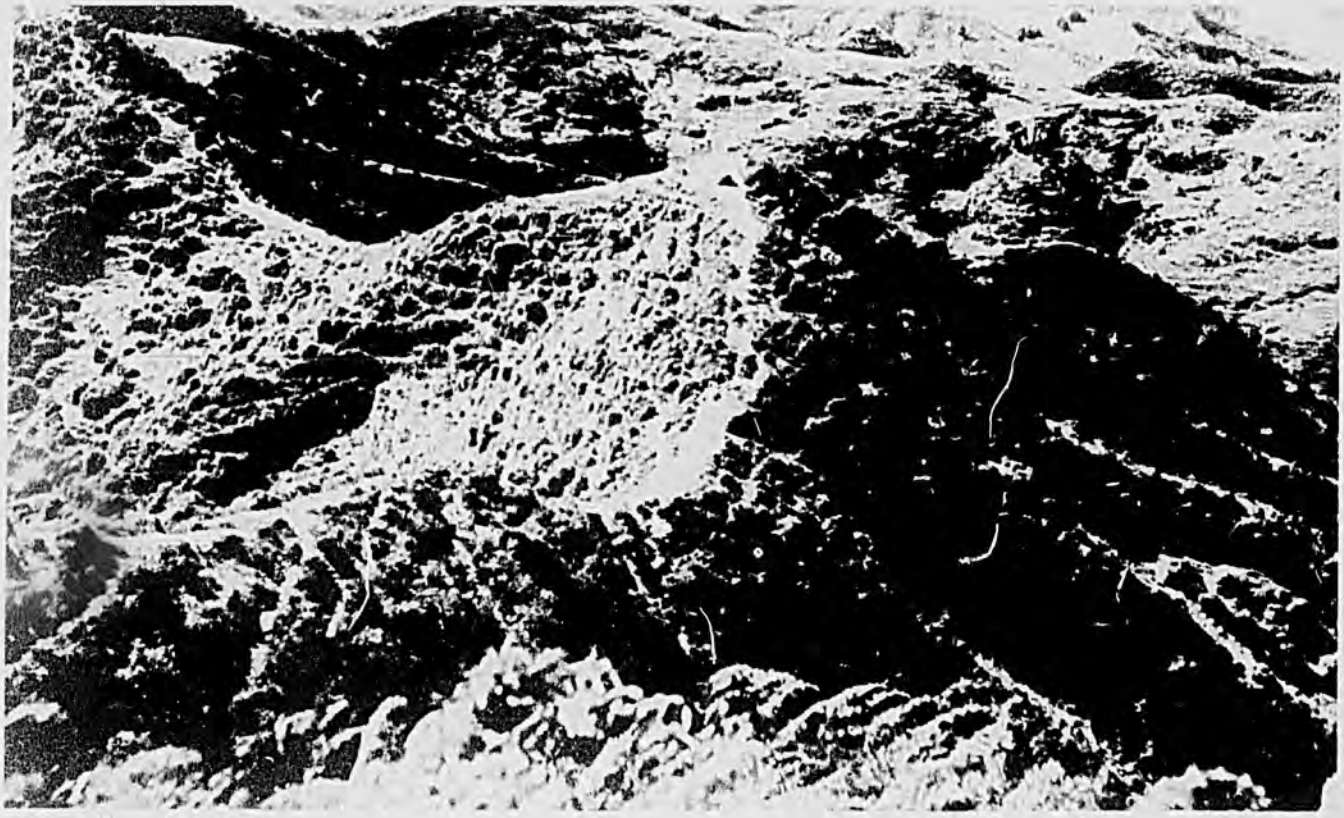
In 1959 when the trial began, all pastures were uniformly short, with no roughage. Paddocks grazed by sheep alone soon developed a dense mat of unpalatable rank herbage, particularly at the lower stocking rates. Even at the highest rate some roughage accumulated on the steep and lower slopes of the paddock. Rank clumps were interspersed with closely grazed patches, so at 7.4 ewes/ha only about 20% of the area was being closely grazed. Close-grazed patches were larger at the higher stocking rates. At 16.1 ewes/ha there were only a few tufts of roughage on the steeper banks, improvement in utilization made by an additional 2.5 ewes/ha was greater between the 9.9 and 12.4 levels than it was between the 7.4 and 9.9 levels. At 16.1 ewes/ha pasture utilization was almost complete.

The two heavier stocking rates maintained pasture in a relatively clean state throughout the year, whereas paddocks grazed by 7.4 and 9.9 ewes/ha were always rough and patch grazed. Within clumps of uneaten roughage, clover was quickly smothered. Accumulation of roughage in the lighter-stocked paddocks was noticeable even in the first year of the trial, a situation that is common on hill farms where attempts to improve pasture by oversowing and topdressing are not followed by adequate stocking to control the increased growth.

Typical steep hill country on which much of New Zealand's store stock is bred

The country on the left has reverted to scrub through lack of adequate subdivision, topdressing legumes, and stock management. The pasture on right is under good management.

Where cattle were used to control surplus grass, pastures were maintained in a uniformly short and palatable state. The lower the sheep stocking rate the more need there was for cattle. At 7.4 ewes/ha a high proportion of the grazing was by cattle but at 16.1 ewes/ha there was practically no need for



Reverted country of this nature can easily be brought back into high production by subdivision, topdressing, seed sowing, and efficient stock management.

Oversown and topdressed hill pasture summer-spelled for reseeding. Note short grass and strong white clover flowering when spelled after hard grazing up to mid-December.

cattle except for short periods in the wetter summers. In these heavily stocked paddocks clover and ryegrass content of the pasture substantially increased.

At all stocking rates in the paddocks grazed by sheep alone coarse weeds rapidly invaded the pasture, especially at the lower stocking rates of 7.4 and 9.9 ewes/ha. However, at 16.1 ewes/ha fern and manuka were under reasonable control. Toetoe, rushes, and sedges were uncontrolled at all sheep-alone stocking rates on both sunny and shady faces; however when cattle were grazed, particularly at heavy rates, these weed problems were not apparent. All weeds mentioned, even toetoe, were grazed by cattle when grass was in short supply.

At the end of five years one of the purposes of the trial had been largely fulfilled—a necessary role for cattle in hill country management had been established. The trial was, therefore, reorganized on the basis of sheep plus cattle on all paddocks for the remaining five years.

The trials showed clearly that a balance of sheep and cattle must be maintained even at the higher sheep stocking rates in order to control coarse weeds and shrubs which sheep will not consume. Sheep alone at high stocking rates have been suggested to control adequately all pasture and weed growth on hill country. The Te Awa trials showed that even at levels of 17.3 ewes/ha sheep will not control all weed growth.

PASTURE QUALITY

The lighter stocked sheep-alone paddocks had much unconsumed herbage at all seasons, and percentages of dead material in this herbage were in inverse proportion to the stocking rate. Where cattle were grazed with sheep, especially at the higher sheep stocking rates, relatively little dead material occurred. At higher sheep stocking dry matter percentage dropped and when cattle were grazed with sheep it was generally lower still.

Throughout the trial, continuously close-grazed pastures under good sheep and cattle management always had a substantial amount of dead material in the herbage samples, the overall average being 22.7%.

Protein content was higher under heavier stocking rates. Average protein content in the sheep-alone paddocks was 15.8% against an average of 18.3% in the sheep-plus-cattle paddocks. Under sheep alone, the samples from the paddocks stocked with 7.4 ewes/ha contained 12.7% protein and those from 16.1 ewes/ha paddocks contained 18.8% protein.

GENERAL CONCLUSIONS FROM STOCKING RATE TRIALS

As stocking rates increased so also did ryegrass content. Overgrazing with sheep alone tended to reduce slightly the clover content and led to an opening up of the pasture during drought with consequent invasion by weeds. Maintenance of a dense, highly productive sward required an adequate but not excessive grazing pressure. The optimum stocking rate for animal and pasture production appeared to be around 12.4 ewes/ha plus 3 to 4 ewe equivalents in cattle on improved pastures.

It was shown by Lancashire and Ulyatt (1974) that as much of the herbage as possible should be consumed as it grew, particularly during the spring months, to keep pastures palatable and nutritious as long as possible. Autumn-grown pastures on the other hand did not become coarse and grazing pressure could be eased. Any carry-over of spring-grown roughage into the winter resulted in competition between cattle and sheep for short succulent herbage. Only when all of the fresh grass had been consumed would cattle graze rough grass. This meant that during winter cattle could subsist on this dead material while sheep virtually starved.

The trials showed that better utilization of pasture with a resultant higher output of animal products was achieved by simply increasing stocking rate. At the higher rates of sheep and cattle stocking, there was a depression in actual production per animal but much higher production per ha.

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DISCUSSION

T. Bedell (Oregon, USA). I infer that you simply oversowed clovers into the bentgrass or into the plants that were there. Do you very heavily graze those areas prior to the time that you sowed them?

Suckling. Yes. We graze it hard and progress from paddock to paddock grazing right to the butt to allow the seed to penetrate to the soil. And wherever practical we followed that up by running the sheep around trying to tramp it in, because this is the only cultivation that one gets in our oversowing. I must say we've got a renewed cycle of effort on our oversowing techniques—there are so many things we don't know about it. The costs are rising rapidly. We have Derek Charlton working on this and I'm sure he'll bring forth a lot more that we've just not shown in ours.

S. Barnhart (Iowa, USA). What kind of management did you use following the overseedings?

Suckling. Well, we did a lot of oversowing experiments, but very briefly the answer is that we found by virtually continuous grazing without overgrazing it was necessary to allow a maximum amount of light to penetrate to the seedlings. If we allowed the grass to come up, the most of our sowing was for the autumn rains—the best time of the year for sowing according to the experiments that we did—and in autumn we tend to get a flush. This tends to smother the plant and so you've got to keep grazing to stop it from smothering the seeds.

R. L. Reid (West Virginia, USA). Could you expand a little on the question of the rightness of the economic climate? To what extent does this have to improve in New Zealand to justify increased improvements of hill land pastures?

Suckling. Well, Dr. Brougham touched on this and I would say that we'd have to get a lot more livestock in terms of overseas returns before much more fertilizer would be put on. Last year we actually dropped from 2 million to about 1.6 million tons.

R. Brougham (New Zealand). It went to about 3 million all over the country.

J. Scholl (Wisconsin, USA). Do I understand that this was forested, cut off, and then consequently your native weed problem wasn't very great?

Suckling. Oh, yes. We went through that cycle. This is the first thing we have to do.

Scholl. What is the nature of this weed problem?

Suckling. Scrubby plants, leptospermum is the main one. In five years from cutting and burning you can be back into a solid mass about 3 or 4 feet high, and in 10 or 12 years it's up to 12 to 15 feet high.

Unidentified. Has your program been eliminating this?

Suckling. Cutting and burning again or pulling by hand when it is very small.

Unidentified. Not by cattle?

Suckling. Yes, or control—as I was saying the biological control factor is most important. Where it was stocked with sheep and cattle at heavy rates they ate all of the leptospermum—they ate it out of the ground.

J. Winch (Canada). One of the major problems as far as utilization of this and good management is concerned is fencing. Fencing is very, very expensive. In our country it's about $1.00/foot. Do you have any words of wisdom as to how such cost might be lowered?

Suckling. On Land Department development blocks we use a Pearce fence, at least that's what we call it. It's a new fence that's been designed by one of the soil conservation people with only about 3 or 4 posts to the chain. The whole thing is a flexi-fence—it swings, it's loose, the battons or droppers are plastic—just looped plastic over the wire and this can be electrified for cattle with just one or two wires. You can use what Ray Brougham showed us on his slides, the netting electric fence, this new plastic one, and, at a later date, the young farmer who gets this allocated Land Development property (because this is the purpose, develop it and then sell it to a young farmer) can put more posts in and more wire on as money permits.

Winch. Have you any idea how much a fence such as this plastic one would cost?

J. Walls (Pennsylvania, USA). I've used some of the fences, about 20 000 feet this season, and it's a thin 12½ guage, high tensile wire. Total cost was 37 cents a foot, and it's very adequate.

M. Heath (Indiana, USA). You and Mr. Brougham alluded to the fact that you have all this input in the development of hill land with your primary livestock industry and then the price cycle works against the continuous use of it. Is there any justification for subsidies for government partnership here to hold the progress of this type of land until they work out of the bottom of this cycle?

Suckling. There is a very small subsidy on transport of fertilizer and lime and also a small one on superphosphate. But there's very little else.

K. F. O'Connor (New Zealand). The country has got to make its money out of selling the stuff so what does the government use for money if we can't sell it?

Suckling. That's right.

R. Brougham (New Zealand). Except, there are other things happening in the country. I think the question has been bothering some of us over the past 3 days. There are schemes afoot to help the internal cost structure, such as acquisition of products from the farmer—wool, wheat, bought by the government—because we're exporting a lot of this. They export and sell it better, frequently in terms of external price, than the individual farmer does and they're trying to take part of the money in good years. This year is a very good year for our products. Wool has never been better except for the pre-Korean 1952 price, and meat has never been better, especially lamb, so that the income at this stage is very high this year for the sheep farmer in the country. The government is taking part of the top off that, putting it in a pool, investing it and then in years when the prices are not so good the money will go into the trough and the farmer will be able to plan better in the development state.

68.

Stabilization of Hill Areas Under Adverse Grazing and Climatic Conditions at Wagga Wagga, New South Wales, Australia

C. M. Adamson

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During the last 100 years, large areas of forested hill land in southeastern New South Wales have been cleared for primary production. Land use is diverse, including arable farming, grazing, and forestry and is determined by topography, soils, and climate, particularly rainfall, which varies from 500 mm per year in the west to over 1 000 mm, with increasing altitude, in the east. Grazing is the principal land use.

Within this area are major water storages for irrigation and urban use. The main catchments affected are those of the Murrumbidgee, Murray, Shoalhaven, and Lachlan rivers. Catchment protection is vital to ensure water quality and quantity. To date more than 1 100 km^2 of grazing country in these catchments have been protected with soil conservation works (Anon., 1975).

Extensive sheet and gully erosion following clearing resulted from increased runoff caused by ground cover reduction due to overgrazing by sheep and rabbits.

Following clearing, pastures were dominated by low-producing perennial native grasses. Increased economic returns were only possible following the regular use of superphosphate and the introduction of improved annual species consisting of subterranean clover (*Trifolium subterraneum* L.) and Wimmera ryegrass (*Lolium rigidum*).

Increased land use intensity will increase the erosion hazard, jeopardizing productivity, the storage life of water reservoirs, and increasing flood risk. Current trends are for increased land use intensity.

The experiments described here were designed to assess the effects on runoff and soil loss of increased stocking rate and the replacement of native pasture with improved annual pasture.

The experiments were conducted at the Wagga

Wagga Soil Conservation Research Center (35° S, 147° E, elevation 230 m) located 400 km southwest of Sydney on the lower western slopes of the Australian Alps. The climate features hot dry summers and cool wet winters (mean temperature range from 24 C to 8 C). Mean annual rainfall is 580 mm per year, which is evenly distributed, with high intensity convectional storms expected during summer.

Experiments were conducted in plots—the Hill Grazing Experiment—and in small catchments—the Comparative Catchment Experiment.

EXPERIMENTAL

The Hill Grazing Experiment

This experiment began in 1948 to assess the effects of heavy and normal stocking rates.

Runoff and soil loss was measured from six 0.01-ha plots (41.47 m × 2.44 m) on a 15% slope with an easterly aspect. The plots were randomly located in three blocks to which heavy and normal grazing treatments were applied. The soil is a Lithosol, Um4.11 (Northcote, 1974), formed *in situ* on Ordovician slate and phyllite. The following species are dominant in the native pasture: *Bothriochloa* spp., *Stipa* spp., and *Danthonia* spp. The introduced annuals *Hordeum* spp., *Trifolium subterraneum*, and *Lolium rigidum* may occur during winter in the heavily grazed plots. Annual dressings of superphosphate were applied. Grazing rate varied depending on seasonal conditions.

The normally grazed plots were managed to maintain ground cover and bulk. This equated to 5 d.s.e. ha^{-1} (dry sheep equivalents) which corresponds with the average stocking rate of a similarly grazed adjacent paddock. Average yearly ground cover on the plots was 87%. Average yearly ground cover on the heavily grazed plots was 65% and average annual stocking rate was 8 d.s.e. ha^{-1}.

Both treatments were mob stocked for short periods.

The Comparative Catchment Experiment

This experiment began in 1951 on two similar, adjacent seven-ha catchments. Average catchment slope is approximately 12%; aspect is easterly. The soil is a yellow solodic—Dy2.42. Deepest soils occur on the lower slopes while Ordovician slate and phyllite outcrops occur on the ridges.

Initially, both catchments were severely eroded. One catchment was treated with contour furrows and pasture improved, the other remained untreated as a control.

Contour furrows were built at one-m vertical intervals to give a depression storage of 40 mm. The improved pasture consists mainly of Wimmera ryegrass and subterranean clover, and annual dressings of superphosphate are applied. During summer *Bothriochloa* spp. become evident.

Both catchments were mob stocked. The treated catchment was grazed to maintain ground cover while the untreated was intensively grazed.

During the experiment the untreated catchment remained severely gullied and sheet eroded while the treated catchment showed no visible deterioration.

RESULTS

The Hill Grazing Experiment

An analysis of variance of annual data showed differences at the 5% level between treatments. There were no significant differences within treatment replications. Average annual results from the two treatments are presented in Table 1.

TABLE 1. Average annual results, hill grazing experiment, Wagga Wagga Research Center, 1950–75, 0.01-ha plots

Item	Normal grazing (N.G.)	Heavy grazing (H.G.)	Ratio (H.G./N.G.)
Stocking rate (d.s.e.[a]/ha)	5	8	1.6
Runoff (mm)	4	13	3.3
Soil loss (kg/ha)	21	205	9.8
Soil carried per unit volume of output (kg/m^{-3})	0.4	1.5	3.7
No. of runoff events (26 years)	91	199	2.2

[a]d.s.e. = dry sheep equivalents.

Increasing stocking rate from 5 to 8 d.s.e. ha^{-1} increased runoff by 3.5 units and soil loss by 10 units.

The results from both treatments were strongly influenced by seasonal conditions (Table 2).

Greatest runoff occurred from late spring storms in October, but highest soil loss occurred from summer storms. Soil carried per unit volume of runoff was greatest for these storms, being 15.5 times greater than the lowest winter level.

High soil loss during summer resulted from high intensity rain when vegetal cover was low. In February, up to 25% of rain falls at intensities greater than 50mm per hour.

The Comparative Catchment Experiment

The hydrological effects of catchment treatment have previously been examined (Adamson, 1976) and are summarized in Table 3.

Stocking rate increased by a factor of 1.8 and runoff and soil loss decreased by 69 and 99%, respectively.

Differences between all means are significant at

TABLE 2. Average monthly results, hill grazing experiment, Wagga Wagga Research Center, 1950–75, 0.01-ha plots

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
						Runoff (mm)							
Normal	0.6	0.8	0.2	0.4	0.2	0.0	0.0	0.2	0.0	1.6*	0.2	0.2	4.4
Heavy	1.2	2.0	1.6	1.4	0.8	0.8	0.6	0.4	0.4	2.2*	0.8	1.2	13.4
						Soil Loss (kg/ha)							
Normal	4	7*	2	1	1	0	0	1	0	4	0	1	21
Heavy	21	32	32	29	19	10	2	2	5	10	4	39*	205
						Soil carried per unit volume of output (kg/m^3)							
													Average
Normal	0.66	0.96*	0.92	0.18	0.80	0.25	0.17	0.44	0.06	0.21	0.20	0.51	1.5
Heavy	1.7	1.4	2.1	2.0	2.6	1.2	0.2	0.5	1.2	0.4	0.5	3.1*	0.45

*Indicates highest values.

TABLE 3. Average annual results, comparative catchment experiment, Wagga Wagga Research Center, 1952–75, 7-ha catchments

Item	Untreated	Treated	Ratio (Treated/untreated)
Stocking rate (d.s.e.[a]/ha)	3.5	6.5	1.8
Runoff (mm)	39	12	0.3
Soil loss (kg/ha)	2 080	30	0.01
Soil carried per unit vol. of output (kg/m^3)	5.42	0.26	0.05
No. of runoff events (24 years)	655	153	0.2
Dry matter production (kg/ha[b])	2 307	5 059	2.2

[a]d.s.e. dry sheep equivalents.
[b]Records from 1973–75.

the 0.2% level ("Z" test). Monthly averages are presented in Table 4.

Greatest runoff and soil loss occurred simultaneously in October when rainfall was highest. Runoff from February storms was most erosive in terms of weight of soil carried per unit volume of runoff.

Seasonal differences in pasture production between catchments caused by differences in botanical composition also influenced hydrologic response. The improved annual pastures in the treated catchment grow most vigorously during winter but provide negligible ground cover and bulk during summer. The effect was to increase runoff during summer. During winter and spring detention storage in the improved pasture was greater than for the perennial native grasses in the untreated catchment (Adamson, 1976).

Seasonal pasture differences were reflected in stocking rates (Table 5).

Stocking rates in the treated catchment are generally twice those in the untreated for the winter-spring

TABLE 4. Average monthly results, comparative catchment experiment, Wagga Wagga Research Center, 1952–75, 7-ha catchment

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
						Runoff (mm)							
Untreated	2.4	1.2	1.6	2.6	1.4	3.6	4.8	3.0	4.4	9.8*	2.4	1.4	38.6
Treated	1.2	0	0	0.4	0	1.4	2.2	0.2	2.8	3.6*	0	0.2	12.0
						Soil Loss (kg/ha)							
Untreated	243	212	175	115	90	109	206	65	164	340*	214	87	2080
Treated	5	1	0	3	0	3	3	0	5	10*	0	0	30
						Soil Carried per Unit Volume of Output (kg/m^3)							
													Average
Untreated	10.4	18.1*	10.8	4.6	6.3	4.8	4.2	2.2	3.8	3.5	8.8	6.0	5.4
Treated	0.42	0.71*	0.69	0.61	0.21	0.19	0.16	0.31	0.17	0.26	0.14	0.18	0.26

*Indicates highest values.

TABLE 5. Average monthly stocking rates,* comparative catchments experiment, Wagga Wagga Research Center, 1949–75, 7-ha catchments

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Untreated pasture	3.5	2.7	2.7	2.2	2.9	3.1	2.2	2.9	3.5	6.3	5.4	4.6
Improved pasture	4.3	3.4	4.7	3.7	6.1	5.4	4.9	5.0	8.1	11.6	7.3	7.5
Improved/untreated	1.2	1.3	1.7	1.7	2.1	1.7	2.2	1.7	2.3	1.8	1.4	1.6

*Dry sheep equivalents per ha (d.s.e.).

growth flush. They approach unity for the summer and increase with pasture germination in autumn.

In grazing situations such as this the specific effect of soil conservation structural works must also be determined. These include (Adamson, 1976) reduction in the number of runnoff events, the number of days of flow, and peak discharge; and increased time of rise to the peak, runoff before and after the peak, and duration of flow recession.

These effects were produced by increased depression storage in the contour furrows and increased detention storage in the improved pasture when actively growing.

Plot and Catchment Relationships

Relationships between monthly surface runoff and soil loss from intensively grazed areas—the heavily grazed plots and untreated catchment—were calculated on a seasonal basis. The relationships were:

Significance Level

Summer

$y = 0.430x + 0.09$; $r = 0.86$ (0.5%); Runoff
$y = 4.06x + 398.3$; $r = 0.89$ (0.5%); Soil Loss

Winter

$y = 0.90x - 0.96$; $r = 0.94$ (0.5%); Runoff
$y = 2.58x + 61.5$; $r = 0.65$ (1%); Soil Loss

Where y = Soil loss, kg ha^{-1} } untreated catchment
Runoff, mm
x = Soil Loss, kg ha^{-1} } heavily grazed plots
Runoff, mm

DISCUSSION

Plot results showed that increasing stocking rate from 5 to 8 d.s.e. per ha increased runoff and hence flood risk three times and soil loss ten times.

The catchment results showed that under intensive grazing unimproved unfertilized land carried only 3.5 d.s.e. per ha. Yet, soil loss was ten times greater than that from heavily grazed plots.

With pasture improvement, regular topdressing, and soil conservation works, stocking rate was nearly doubled and approached that of the heavily grazed plot treatment. Soil loss was reduced to the level of the normally grazed plots.

These results illustrate the difficulties in extrapolating plot data to larger areas.

In these experiments the differences resulted from changes to overland flow as determined by slope length, while the contribution of subsurface flow is not measured in plots.

Where the length of overland flow was restricted, as in the plots and treated catchment by the contour furrows, greatest soil loss reduction occurred. Without restrictions, as in the untreated catchment, soil loss was accelerated due to erosion of drainage lines caused by runoff becoming channelized.

Significant relationships, however, were derived between the plot and catchment data, providing runoff or soil loss resulted from overland flow.

Replacement of native grass vegetation by improved pasture increased detention storage when the pasture was actively growing. However, following senescence runoff could be increased. In a similar environment Dunnin (1965) showed that peak discharges could also be increased following senescence of improved annual pasture without soil conservation structures.

The replacement of native by improved pasture increased productivity and stocking rate but, due to seasonal plant growth changes which affected the hydrological characteristics of the pasture, the erosion hazard may be increased.

Pasture management to maintain ground cover and storage following pasture senescence is impractical because the standing dry pasture is used as reserve summer feed. Consequently, soil conservation structural earthworks, which increase detention and depression storage, are an essential adjunct to improved land management practices. Soil conservation works also allow greater year round grazing management flexibility since erosion protection is also provided by the structures rather than the vegetation alone.

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DISCUSSION

K. O'Connor (New Zealand). Could you give us some idea of the difference in infiltration rates between the improved pasture without furrows and the untreated pasture? Also, what's the effect on your runoff and stock-yield if you just have the improved pasture without going to the furrows?

Adamson. I'll answer the first question first. We don't have results on the infiltration rates on the native and improved pasture. We can only surmise that infiltration rates have been increased. We do, however, have loss rates from these catchments and loss from the treated catchment with the contour furrows is very great. The effect, I think here, is mainly caused by the contour furrows. As to the second question, we do have plot data and under improved pasture with no soil conservation, which we of course couldn't put into the plots, we did get an increase in runoff during the summer months.

J. Phelan (Virginia, USA). The terraces that you showed, are they level and plummeting, or are they gradient drainage type?

Adamson. We have two types of terraces. We call them banks. In the catchments on which the work was done, these were level or on the contour. In this case the contour furrows are laid out in that catchment at 1 m vertical intervals, and the actual amount of depression storage within them approaches 40 mm. The other type of bank that we used has a gradient within the channel and this one we call a gradient bank. These are the ones that we mainly use for increasing retention storage.

69.
Upland Soils of County Leitrim, Ireland

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County Leitrim (Fig. 1) is situated in northcentral Ireland between 53°48′ and 54°29′ N and 7°35′ and 8°24′ W. A detailed reconnaissance soil survey of the county has been completed by Walsh (1973). The uplands are considered as those areas which rise above the drumlin packed lowland. They occupy about 24% of the county. This paper gives an account of some of the chemical and physical characteristics and genesis of these soils and of their general suitability for agriculture.

The lowland drumlin soils, derived from glacial drift, have a high clay content and a weaker soil structure than the mountain soils which are derived from colluvium and limestone bedrock.

TOPOGRAPHY

The uplands occur in the northern half of the county and range in elevation from about 60 m at the base to 610 m at the summit. Most of the uplands or mountains are table-like, although the summit topography varies from undulating to rolling and is rarely level. They are incised by deep valleys, some of which are narrow and steep-sided, e.g., Glenade and Glencar, and others which are broad with more gently sloping sides, e.g., Glenfarne and Drumkeeran.

Benbo Mountain, near Manorhamilton, contrasts with the surrounding mountains because of its smooth dome-like shape.

GEOLOGY

About half of the upland area consists of Lower Carboniferous deposits such as limestone, calcareous shale and sandstone. Most of the remaining upland consists of Upper Carboniferous deposits such as shale with coal measures, sandstone and conglomerate (Fig. 2).

Benbo Mountain contains rocks of the Moinian (pre-Cambrian) series—granites, gneisses, quartzites, and mica-schists—which are highly metamorphosed and folded.

CLIMATE

The mean annual precipitation, fairly evenly distributed throughout the year, is in excess of 1250 mm, with the more elevated areas receiving more

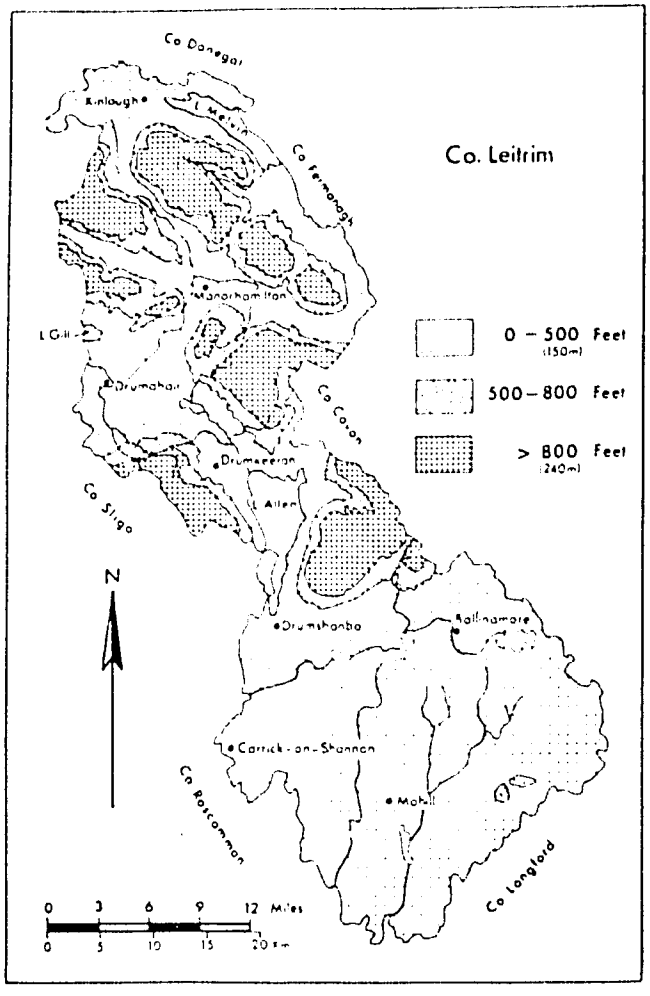

Figure 1. Relative relief features of County Leitrim.

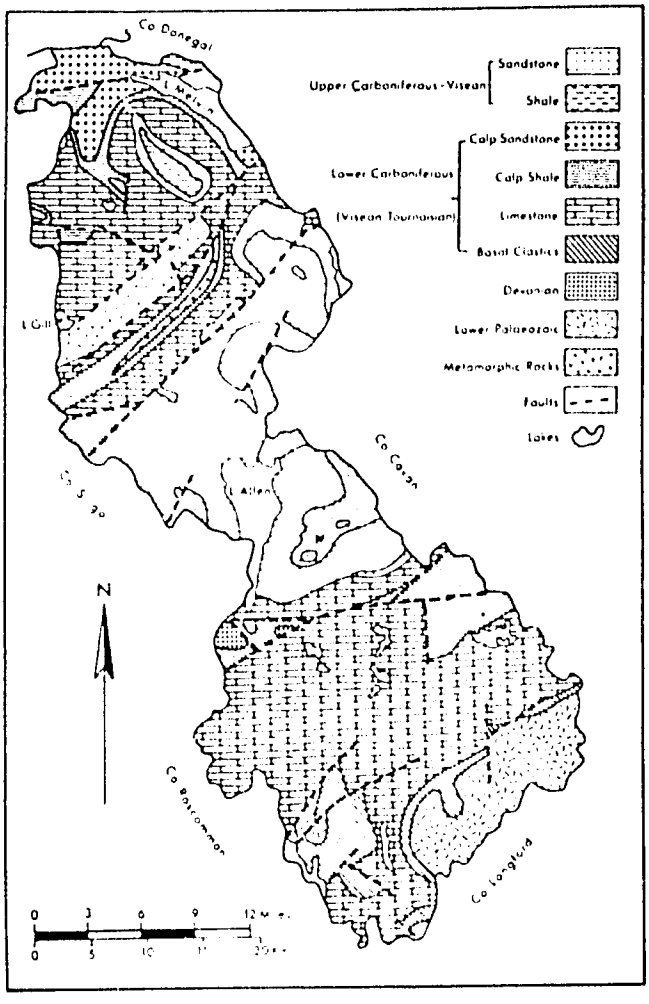

Figure 2. Solid geological formations in County Leitrim—N. B. Dhonau (An Foras Taluntais, 1973).

than 1500 mm. Mulqueen (1971) estimated that annual rainfall exceeds annual potential evapotranspiration by approximately 800 mm.

Mean daily air temperature is about 9° C. It ranges from 5° C in winter to 14° C in summer.

FIELD SURVEY AND ANALYTICAL METHODS

The primary category used in mapping was the soil series. A soil series comprises soils developed from a similar parent material with similar type and arrangement of horizons. Field mapping was carried out at a scale of 6 inches to 1 mile (1:10560).

Representative soil profiles were examined and described according to the 1962 supplement to the *Soil Survey Manual*, USDA Handbook No. 18, 1951. Soil taxonomy of the 7th approximation is also given.

The analytical methods used are summarized as follows:

Particle Size Analysis: Determined by the International Pipette Method as described by Kilmer and Alexander (1949), using sodium hexametaphosphate as dispersing agent.

Cation Exchange Capacity: Determined by the method of Mehlich (1948). Soil was leached with buffered $BaCl_2$ to displace exchangeable cations; Ba displaced by $CaCl_2$ and K_2CrO_4 was used in the colorimetric estimation.

Total Exchangeable Bases: Extracted by method of Mehlich (1948). Ca, Na, and K estimated flame photometrically, Mg by titan yellow method.

pH: Determined on 1:2 soil/water suspension using a glass electrode.

Organic Carbon: Estimated by the Walkley-Black dichromate oxidation method as described by Jackson (1958), modified for colorimetric estimation. Values were read on a Spekker Absorptiometer using Orange Filter No. 607. A recovery factor of 1.1 was used.

Total Nitrogen: Estimated by a modification of the method of Piper (1950) by digesting soil with conc. H_2SO_4 using selenium as a catalyst, distilling into boric acid, and titrating with HCl.

Free Iron: Extracted with buffered sodium hydrosulphite (Mehra and Jackson, 1960) and Fe determined colorimetrically using o-phenanthroline.

THE SOILS

The soils are considered in two broad groups, mineral and organic. The mineral soils include Crumpaun, Loughmuirran, and Burren series and Drumkeeran Peaty phase. The organic soils are represented by the Aughty Series.

Mineral Soils

The Crumpaun Series is a lithosol (Lithic dystrochrept), 5 to 15 cm deep, which occurs on scree slopes at elevations of 210 to 400 m. Slopes average 40°. The scree material is broken off cliff faces which consist of limestone with some shaley partings of Lower Carboniferous age. The soil has an A, C profile with a diffuse boundary between the two horizons, well to excessively drained of silt loam to silty clay loam texture, and of low base status. Organic matter content varies from 10 to 15% and cation exchange capacity (C.E.C.) from 30 to 49 meq/100 g. Soil pH is low, ranging from 5.0 to 5.4, despite the limestone nature of the parent material. This is due mainly to the high annual rainfall and excessive stoniness of the soil.

The Loughmuirran Series is a brown earth (Dystrochrept) of variable depth, 26 to 80 cm. It occurs on colluvial slopes at elevations of 120 to 240 m. The slopes range from 22 to 35°. The colluvium is derived mainly from calcareous shales and limestones of Lower Carboniferous age. The soils may have an A, C, or an A, (B), C profile. They are moderately to imperfectly drained, of silty clay texture, and of low to medium base status. Organic matter content of the surface horizon ranges from 11 to 17% and the C.E.C. averages 45 meq/100 g. Soil structure is weak.

The Burren Series is a shallow rendzina-like soil (Lithic eutrochrept) 20 to 35 cm deep. It occurs on hill and mountain topography which rises from 70 to 400 m. Slopes ranging from 10 to 15° are common. The parent material consists of bedrock of Lower Carboniferous age which includes limestones and calcareous shales or of shallow glacial drift which is derived from these rocks. The soil has an A, C/R profile. The soil is well to excessively drained, of high base status, and of clay loam texture. The organic matter content of the surface horizon is about 15% and C.E.C. 44 meq/100 g. Soil structure is weak to moderate and rock outcrop is frequent.

The Drumkeeran Series, Peaty phase, is a mineral soil but with an organic surface horizon. The soil is a peaty gley (Histic humaquept) which occurs on mountain slopes of 8 to 15°, and between 150 and 300 m. The parent material consists of glacial drift derived mainly from carbonaceous shales, some sandstones, and limestones. The rocks are mainly of Upper Carboniferous age. The soil profile consists of O, Bg, Cg horizonation. The soil has poor natural drainage, organic clay to silty clay texture, and medium to low base status. It is massive, sticky, and plastic with 70% clay in the B horizon. The surface horizon has 57% clay and 36% organic matter.

Organic Soils

The Aughty Series is blanket or climatic peat. It covers the summits of all the mountains and is 1 to 2 m deep. The profile is raw in nature with no evidence of soil amelioration. The peat is relatively homogenous throughout and is composed dominantly of cyperaceous plant remains with some Sphagnum spp. embedded in a greasy humified matrix.

SOIL SUITABILITY

Mineral Soils

The Crumpaun, Loughmuirran, and 70% of the Burren Series (Burren B) cannot be fertilized because of very steep slopes. There are no experimental results for grazing potential available for these soils, thus their grazing capacity is based on existing production (Table 1). This is equivalent to 49 livestock units per 100 ha (Lee and Walsh, 1973). A livestock unit is taken as a 533 kg (10.5 cwt) animal or its equivalent.

The remaining 30% of the Burren Series (Burren A) is accessible to mechanization. It has a grazing capacity of 235 livestock units per 100 ha with application of 230 kg N per ha.

The Drumkeeran Peaty phase is a difficult soil to either farm or reclaim successfully. Any farming enterprise is hampered by the very weakly structured or structureless topsoil. Reclamation, especially drainage, is hampered by a plastic, impervious subsoil and by frequent occurrence of sandstone boulders. Most of the area, however, is accessible to mechanization.

Animal production and pasture dry matter output data from An Foras Taluntais Research Station at Ballinamore, which occurs on a fairly similar soil, provide the basis for the grazing capacity estimates for this soil.

The grazing capacity of the remaining soils is estimated by comparison with stocking rate trials on An Foras Taluntais farms which occur on somewhat similar soils. Thus in these estimates, optimum management techniques are assumed and interfarm variability ignored.

TABLE 1.* Grazing capacity of upland soils in County Leitrim, Ireland

Soils	Area (ha)	48 kg N/ha Grazing capacity (livestock units/100 ha)	48 kg N/ha Gross grazing capacity (000 L.U)	230 kg N/ha Grazing capacity (livestock units/100 ha)	230 kg N/ha Gross grazing capacity (000 L.U.)
Crumpaun	715	49	353	—	—
Loughmuirran	222	49	110	—	—
Burren B	1 000	49	495	—	—
Burren A	767	188	864	235	1 006
Drumkeeran Peaty phase	2 923	124	3 611	—	—

*Lee and Walsh (1973).

Organic Soils

The Aughty Series, which caps all the mountains and their upper slopes, are generally unsuitable either for agriculture or forestry. This is due to the poor nature of the soils and to exposure at these elevations.

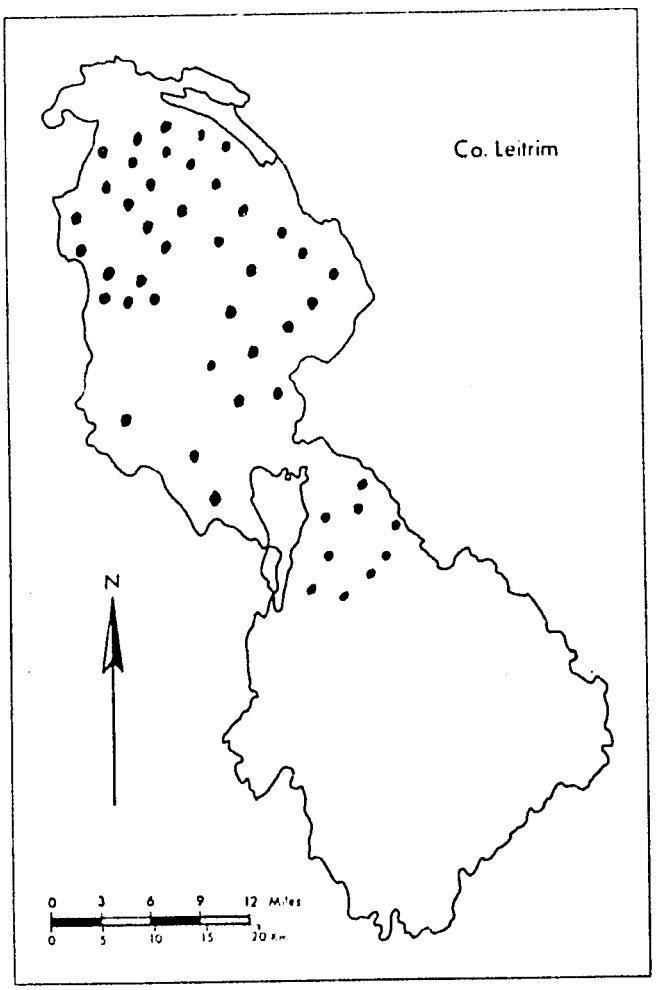

Figure 3. Sheep population distribution in County Leitrim. Each dot represents 500 sheep.

MOUNTAIN SHEEP DISTRIBUTION

The sheep distribution map (Fig. 3) shows that about two-thirds of the total numbers of sheep are concentrated in the northern part of the county, coinciding with the dry mountain soils—Crumpaun, Loughmuirran, and Burren—which are derived from Lower Carboniferous deposits. South of this area, sheep numbers decrease as the wetter and more plastic soils such as Drumkeeran Series, Peaty phase predominate.

ACKNOWLEDGMENTS

The author acknowledges the cooperation of those who participated in the soil survey of County Leitrim (An Foras Taluntais, 1973), the help of Dr. J. Lee with the grazing capacity estimates of the various soils, and Mr. M. O'Toole who supplied the data on the distribution of the sheep population in County Leitrim.

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DISCUSSION

E. J. Ravalo (Puerto Rico). You mentioned that accessibility to machinery is a basic consideration in your land use planning. What operation and type of machinery are you using in mechanizing operation for these steep slopes? Is it designed locally or available on the world market?

M. O'Toole. There are a few simple rules that you can apply to land. Normally, you use most agricultural machinery from 20 to 18 degrees. But from 20 degrees you need specialized ground machinery and when you go over 23 degrees, maybe apart from the New Zealand motor bikes, I think you ought to take to the air. The type of machine we find more suitable for this is what we call the land rise spreader—a spreader attached to a high-powered tractor where you have four-wheel drive and the drive of the tractor is transmitted to the spreader. It will apply ground limestone up to about 23 degrees. On our hills, apart from the table-like plates I showed you first, we have an acid situation. You will not get good white clover growth without applying about three tons of ground limestone. Now it's not practicable, as far as I know, to apply three tons of ground limestone from the air, so we have to concentrate, then, on the lower foothills.

J. Pearce (Reading, England). Does the EEC directive help in your conditions? Also, is the land tenure system in the area a problem?

O'Toole. I'll take land tenure first. Farm size is small and there is the history of land-locked tenant farming in the area. Following up on that, there are small holdings, maybe 20 to 30 ha, around the homestead. Then you have common grazing. This is a real problem because with common grazing you cannot get the type of development you want. Now, we have a body in Ireland responsible for the division of the land, the Irish Land Commission. Only recently it got compulsory power to divide against the will of the people. As the system was, division was done only with full agreement. It's very hard to get full agreement when you've a big number involved in a common grazing, particularly opposing some older people who have no great interest in intensive agriculture at this stage. There has been a change in this — this should bring about an improvement.

Now the question as to what extent do we find E.E.C. directive 1.9, I think it is, suited to our conditions—I'm afraid not too well because of the smaller farm size. E.E.C. 1.9 is aimed at getting farm viability, in other words, the farm unit which would support a family. Now many of our farms are too small. You need to think in terms of at least 500 acres of the best hill land for this type of income and quite a lot of our farms are not that size. Now the population structure of the area suggests that there's going to be a lot of amalgamation of holdings because of ownership by older people there—no one to farm the land. This will happen in time. That of course presents another problem. You get the people out to make bigger farms and then you're presented with the problem of supporting school structures, the various services in the area that become much more difficult than in a smaller population.

70.
The Development of Lowland Hill Tussock Grasslands in South East New Zealand

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The area lies within the region of 46° 20′ S and 169° 30′ E in the southeast part of the South Island of New Zealand. The land mass is mainly greywacke sedimentary deposits, extensively covered with greywacke loess.

The main soils are lowland yellow-brown earths (N.Z. Soil Bureau, 1968), hygrous—which do not readily dry out. In its native state the the soil pH is about 5.1 and the fertility level is very low, soils being especially deficient in P, S, N, and Mo. Altitude range is 120 m to 670 m. Annual rainfall varies from 750 mm to 1 350 mm, averaging 1 125 mm, and is fairly evenly spread throughout the year. The mean daily temperature at 300 m A.S.L. (N.Z. Meteorological Service, 1976, personal communication) for summer (January) is 12.5° C and for winter (July) 2.6° C.

Average winter period is about 100 days, but livestock are grazed *in situ* throughout the year and are not housed.

In its native state the land cover was mainly tussock grasslands with some native fern, scrub and bush. Dominant grass species are dense red tussock (*Chionochloa rubra*), and fescue tussock (*Festuca novae zelandiae*), interspersed with many other low-producing species, principally browntop (*Agrostis tenuis*), sweet vernal (*Anthoxanthum odoratum*), Yorkshire fog (*Holcus lanatus*), and *Poa pratensis*.

The area covers about 80 000 ha and farm holdings vary from about 160 ha to 3 500 ha, averaging about 800 ha. In the native state these grasslands have a DM production of about 1 500 kg/ha (Daly, 1973) and a known carrying capacity of 0.6 EE/ha.* Since the early settlement of the area about 1850 to the early 1950's the land was developed and farmed for breeding store sheep and store beef cattle, with very few properties being able to fatten their livestock.

Initial development was concentrated mainly on the easy land along the valleys and access roads, leaving the hills in their extensive native state. This lack of development was due partly to the insecurity of leasehold land tenure, much of the land being government land held by tenants on non-renewable leases of various types, and partly due to the lack of technology.

*EE: 1 ewe equivalent = 1 Romney breeding ewe; a standard stock unit for sheep and beef cattle production in N.Z.

DEVELOPMENT

Over the past two decades most of the farm properties in the area have intensively developed their tussock hill land and have carried its potential beyond store stock production. They are now able to fatten all their livestock.

From research technology carried out by government agencies and other research institutions, farm management consultants have been able to assess a potential livestock capacity for this hill land of at least 15 EE/ha on plowable land and 7.5 EE/ha on unplowable land.

Where applicable the land tenure problem was overcome by making the leases long term (mostly 33 years), perpetually renewable with reasonable rentals, and giving security and incentive to develop the land with all improvements being owned by the leasee.

Technology has shown that the soil is most responsive to lime, P, S, and Mo and, in some circumstances K, and extensive research trials (During, 1973) have helped to assess their economic applications.

The main problem on all our hill country in New Zealand is in raising its fertility, which in the undeveloped state is too low to carry a permanent high-producing pasture. This problem is basically overcome by applying fertilizer and introducing clovers to fix atmospheric nitrogen. The undeveloped tussock hill grasslands are practically devoid of efficient legumes, especially the highest producing clovers like *T. repens* and *T. pratense*.

Over the past twenty years three very important factors have made the economic development of this hill country possible. *First*, the economic availability of superphosphate; *second*, the discovery of the extraordinary response to molybdenum (Cullen, 1955) when applied with superphosphate in establishing and increasing the production of high producing clovers; and *third*, the highly sophisticated development of light aircraft for applying fertilizer, seed, weedicides, and pesticides.

PASTURE DEVELOPMENT TECHNIQUES

The chief target of development has been to establish higher producing pasture species for animal grazing production and is being achieved in two main ways: by cultivation and regrassing the plowable land, and by oversowing and topdressing the unplowable grazable land. Both are integrated in an overall plan of general farm development taking into account economic viability, availability of finance, labor, equipment, materials, contractors, additional livestock, and managerial considerations.

Cultivation and Regrassing

The justification for plowing and cultivating where practicable is mainly to have sufficient first-class pasture for making hay and silage for supplementary winter forage and for special management purposes, in particular fattening lambs and cattle.

Briefly, it is best to plow the tussock and scrub in the early autumn (March) with a single- or double-furrowed swamp plow and the furrows left to mellow until the spring. The type of equipment used depends on the contour, topography, and vegetative cover. In the spring the land is disced and leveled and prepared for sowing in a brassica root crop. Usually 2.5 MT/ha of lime is applied before sowing, which will raise the pH about 0.4. Soft turnip (*Brassica rapa*) is the best brassica crop in this virgin soil and does better than swedes (*B. napus*) because the soil is very low in P, N, and organic matter. Generally 500 kg/ha of reverted superphosphate is applied and sometimes also some form of nitrogen.

Soft turnip will yield about 50 MT/ha of green material and will be grazed off *in situ* by sheep and cattle during the winter months (June-August), helping to build fertility through dung and urine return.

In the following late spring (November) the area is sown into pasture. No further plowing is done as this would bring unrotted tussock to the surface and only discing and final leveling is necessary. A further 2.5 MT/ha of lime is applied together with 500 kg/ha of superphosphate and 210 gm/ha of sodium molybdate. The last provides the extra magic for the successful establishment of clovers even though a total of 5 MT/ha of lime will have been applied.

During initial development lime, plus superphosphate, plus Mo, will give best results.

A grass seed mixture containing 16 kg of ryegrass (Ruanui *Lolium perenne*), Ariki and Manawa (*L. perenne* × *L. multiflorum*), 3.5 kg Apanui cocksfoot (*Dactylis glomerata*), 2 kg Kahu timothy (*Phleum pratense*), and 3.5 kg Huia white clover (*Trifolium repens*) is favored. The total of 25 kg/ha is usually broadcast sown with a roller-drill machine. Red clover (*T. pratense*) is not much favored because of possible oestrogenic upsets in the fertility cycle of breeding ewes at mating time.

Following successful establishment, and with sound maintenance and grazing management, these developed pastures will carry 12–15 EE/ha and will be of a quality suitable to fatten lambs and cattle.

We find it important to topdress these pastures annually with 375 kg/ha of superphosphate and to include 210 gm/ha of Mo every fourth year, combined with, if necessary, 3.5 to 5.5 kg/ha of Cu if an induced Mo-Cu imbalance is likely to occur (During, 1973).

Hill Country Oversowing Techniques

Tussock hill country pasture improvement by oversowing and topdressing is more complicated and requires certain golden rules for success, including time of application and cover management before and after sowing.

Ideally, the area to be treated is first well fenced off and, if possible, is heavily grazed with sheep or cattle to open up the cover. If this is not possible, occasionally controlled burning in the preceding spring or summer is a successful means of pre-sowing preparation, but this must be done before any new fences are erected. Experience and research have shown that the best time to apply the initial fertilizer and seed is late winter to early spring (mid-July to mid-September) while the moisture content of the soil is still good and before any drying out takes place.

We have found that the fertilizer and seed is best sown separately by a light aircraft, single-engined 1 MT capacity, and when the seed is sown a Transland Swathmaster apparatus is fitted to the aircraft to insure the best possible spreading effect, about 20–25 m wide on the ground.

The initial fertilizer is usually applied at the rate of 250–500 kg/ha of superphosphate containing 210 gm/ha of sodium molybdate; without the latter, results would be poor.

In many cases only 3.5 kg/ha of Huia white clover (*T. repens*) is sown. This is sufficient to give a dense establishment of clover, which will produce excellent high protein fodder for sheep and cattle and fix nitrogen which will ultimately sustain higher producing grasses. In other cases 2.5 kg/ha of Apanui cocksfoot (*Dactylis glomerata*) and 9 kg/ha of Ruanui ryegrass (*L. perenne*) and sometimes 2.5 kg/ha of Turoa red clover (*T. pratense*) are included. However, grasses in the initial stages do seem to take several years to become established as a viable part of the pasture content. Also, farmers in this area have learned through bitter experience that it pays to sow only certified seeds having a purity of 99% and germination of 90% plus.

In some undeveloped hill country areas it is often difficult to establish clovers (Cullen, 1971) because

of the lack of suitable *Rhizobium* being present in the soil. Best results are obtained either by inoculating the seed with rhizobia just prior to sowing, or by sowing inoculated pelleted seed. Both of these methods have been used in this area with good results.

Throughout the first summer, frequent rotational grazing management with large numbers of sheep or cattle is necessary to keep the vegetation close-grazed and let in plenty of light for the clover to establish. Then, in the second summer the opposite is practiced, when the pasture is lightly grazed or spelled, allowing the clover to reseed and greatly regenerate.

From this stage forward, provided the pasture is adequately maintained with annual or biennial superphosphate topdressing with Mo every four years, and good grazing management is carried out, a carrying capacity of 7.5 EE/ha is achieved. We can expect this to rise to 11 EE/ha in the near future as the fertility is built up and farmers upgrade their overall management.

An example of the annual increase in farm production being obtained in this hill country area is shown (Fig. 1). It shows the mean total sheep and cattle as EE stock units wintered per farm, for seven farms surveyed, from 1962–1976. The average area is 1090 ha and, over the period, sheep numbers have increased by 90% and cattle by 321% giving an overall increase of 145% in EE for the period.

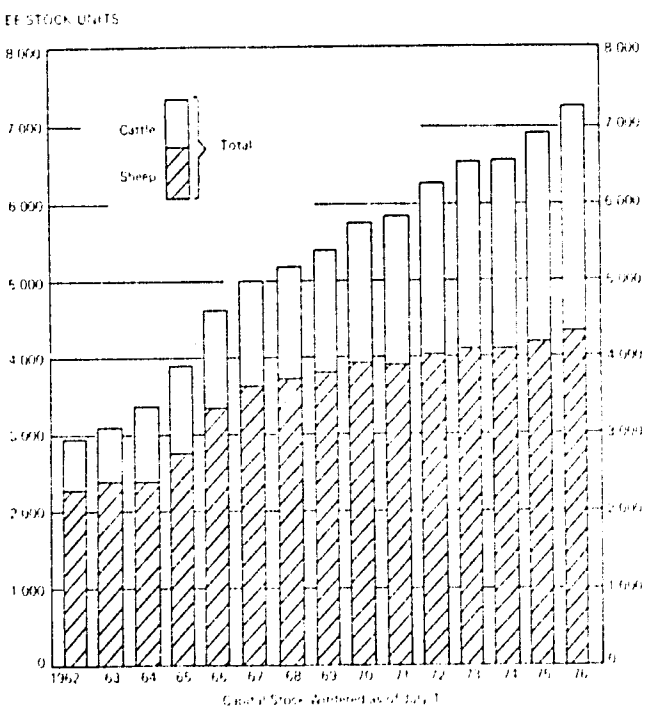

Figure 1. Mean total sheep and cattle wintered per farm for seven farms surveyed in South Otago Tussock hill country.

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DISCUSSION

R. Blaser (Virginia, USA). Could you achieve this kind of success by sod-seeding and adequate fertilization at a little lower cost by requiring much more time to develop such big pastures?

Pantall. The difficulties would be that the land mass itself would be too rough to be suitable for a sod-seeding machine. The land is very rough indeed in its undeveloped stage in the tussock stage and also in the tussocks themselves. I don't think such a machine would do the job. One of the reasons for plowing, of course, is to have some flat areas or easy areas to get over that you can mow.

Blaser. Of course, you get lime and phosphate incorporation.

Pantall. Yes.

Unidentified. You gave the seeding rates of a new pasture. They seem to me very high. Could you tell us why those rates would be so high?

Pantall. In our experience, there are some farmers that, with very good seed bed preparation and good sowing methods, can get away with lighter seeding rates. What do you consider to be an average seeding rate in what you're talking about?

Unidentified. For white clover, for example, we think that two pounds is satisfactory.

Pantall. Well, this is three pounds per acre being sowed. You could sow two pounds, it would be quite all right.

Unidentified. And in a good seed bed a pound and a half is plenty.

Pantall. You're dealing with native country that is very rough and I think it pays to be reasonable with the seeding rates that you're using. I would agree wholeheartedly. The per acre basis is 28 pounds but some farmers can sow as low as 20 and get quite good results. I wouldn't advocate going lower than that. We're dealing with practical farmers and not all farmers are absolutely tops.

K. F. O'Connor (New Zealand). If you want to put up your capital costs of machinery, try renewing sod-seeders every year. It's really the answer to that question. That country kills sod-seeders. Good swamp plows survive. As to why such high seeding rates on new seed beds, the main factor that's dominated New Zealand farmers and to which I think the agronomists conceded, is that farmers want to have stock on pastures within six weeks of sowing. Therefore, they have high seed rates. Why do they want to have animals on pastures within six weeks of sowing? Because animals are there for weed control. Combine the factor of getting the animals on early to control weeds by grazing when the weeds are still soft and to get a sole of grass so that the turf does not deform with the early animal pitting, and these are the main reason why we produce our own seed cheap enough to use very high seed rates.

Unidentified. The question of phosphorus is very important in your situation. Doesn't the future supply of phosphate and its cost worry you?

Pantall. The actual supply may be all right for the future of New Zealand. Professor O'Connor could give a better answer to that. As to cost, our government does subsidize the superphosphate quite extensively. Recently the subsidy has been reduced by $10.00 per pound as a means of trying to get farmers not to put so much on. I don't think there are any real problems.

J. Winch (Canada). You have basically two systems of improving these pastures. One is a swamp plow—I'm not sure what a swamp plow is.

Pantall. It's a very big plow. It turns everything over, buries all the trash, and has a very big furrow.

Winch. You have that system plus the over-sowing. What is the possibility of success of over-sowing over the years? Is it successful every year or what is the probability of getting a good stand versus the plowing system? And, secondly, what are the comparative costs?

Pantall. The costs of over-sowing and top-dressing are much less costly than plowing and cultivating. But by the same token the production, immediate production, that we can get off this land, as I illustrated to you, is from 0.6 ewe equivalents per ha to 15 ewe equivalents per ha, a very dramatic increase in productivity. The unplowed new land, of course, can only be serviced by the airplane and here again we are able to achieve excellent results. In the long run I think that in a relatively short time, say ten years, a lot of this tussock land that we had over-sown and top-dressed that cannot be plowed will be up to 11 ewe equivalents per ha because of the increase in fertility. Costs are rising all the time. It would cost us something like $40 per acre to over-sow and top-dress. With grasses and clovers and fertilizers it would cost about $100 per acre for cultivation and seeding. Bear in mind that we're going to get a crop off that land—turnips—until the time that we go into new grass.

W. Templeton (Kentucky, USA). You indicated that you had successful results from pelleted and inoculated seed. I wonder what you could tell us about the storage life of this seed once it's pelleted and inoculated? How soon does it have to be sown and under what conditions will the inoculum persist satisfactory?

Pantall. Well, with the straight inoculant where you inoculate the seed yourself, it's best that it be done the day it is sown. It could be done the day before and it must not be done in strong sunlight; it should be done preferably either late in the evening and bagged up again or done first thing in the morning. I don't think it should be allowed any longer time than that. With the pelleted seed, however, that will keep for a very long time. In fact, that is done on a commercial basis—it is pelleted by commercial firms so that you buy it through the stock firm and I'm not sure what the life would be, but I'm sure Professor O'Connor would perhaps be able to answer that.

O'Connor. Twenty-one days.

S. Powles (Michigan, USA). You mentioned that you were getting responses from molybdenum and you said that you also raised the pH only by .4, which would raise your pH to about 5.5. Were you getting responses to the molybdenum at that level?

Pantall. Yes.

Powles. So, you're sowing into a pH of 5.5 and then the molybdenum response was above that.

Pantall. Yes.

71.
The Contouring of Hill Land Into Linked Narrow Terraces for Tree Cultivation

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Land arrangement into narrow terraces (Lisa and Luppi, 1967) and, subsequently, into terraces linked by groups (Lisa, 1968) was suggested in order to control the flow of rainwater with tree cultivation in rows on hillsides and at the same time to facilitate the use of agricultural machines for full mechanization.

The topography of the region (Monferrato, Piedmont, N. Italy, 8° N, 45°5′ E) in which the research was carried out is characterized by uneven hills with generally small irregular shaped fields—rarely more than 1 ha, on the average only 0.45 ha—with irregular slope, almost always steep, up to more than 50% gradient.

The soil, which is derived from the decomposition of marls and sandy-fossil limestones, is of various depth and lies directly on the bedrock. It is rather limey and sufficiently fertile. The granulometric analysis shows the following average data:

2–0.2 mm	20%
0.2–0.02 mm	42%
0.02–0.002 mm	24%
<0.002 mm	14%

The average rainfall of the area is 764 mm yearly, mainly distributed in spring and autumn, with summer storms and snow in winter.

The property is parcelled out and the farms are generally of the owner-operator type, mostly of small size (average size: 3.7 ha, with 42.7% smaller than 3 ha).

The main cultivation is grape growing; other crops are forages, for cattle breeding in family-run farms, and cereals production.

The basic principle followed for terrace construction is that rows are arranged following the contour lines but they are given a slight longitudinal gradient so that the rainwater can be safely discharged into the main drain, as adopted in American terracing (Beasley, 1958). In this case, however, when the inter-rows have an inward gradient the water runs along the rows in the drainage channels uphill of the inter-row. When the cross slope of the terraces is left unchanged or only slightly reduced the water runs in the furrows opened in every inter-row by tillage operations.

Another basic principle used in contouring hill land into narrow terraces with reduction of the cross slope consists of joining terraces at the ends, at the same level, to facilitate the operation of farm machinery, especially with regard to turning operation at the head-lands, by eliminating sharp and dangerous changes of gradient.

Following these two principles and taking into account the different soil conditions and the various needs of the crops, a number of hill land arrangements have been suggested and experimented upon.

Fig. 1 illustrates an example of arrangement with narrow terraces, with an inward slope and a 2% longitudinal gradient in alternate directions. Sixteen 1 411 m long contoured rows, with a 3.5 m inter-row, were created on a 5.027 square m plot with an average cross slope of 27%.

Two neighboring terraces had the longitudinal slope in opposite directions. Therefore, at their ends they joined two-by-two at the same level. This produced an area twice as wide as the single terrace (in this case 4.8 m) for the turning of tractors. Each terrace was not linked at both ends with the adjoining ones, but joined at one end to the terrace above and at the other end to the terrace below (Fig. 2).

The tractors must zigzag along the terraces. The rainwater runs off alternatively at one headland and then the other into the drains.

The land was terraced in 1963, and the following year hedge-trained plum trees were planted on the downward edge of the terraces. As the difference in level between the terraces was about 1 m, the downward strip of the terrace was covered by a layer of loose soil sufficient to plant the trees without preliminary deep plowing.

After the final settlement of the backslopes, which attained a 90% slope where there were medium-textured soil conditions, the terraces were about 2 m wide and, therefore, were easy to farm with the usual machines.

The width of the areas at the headlands was about 4.5–5 m, depending on the gradient of the land, and allowed the turning of tractors with mounted implements. However, the areas were not really big enough for turning trailers and other big, towed machinery.

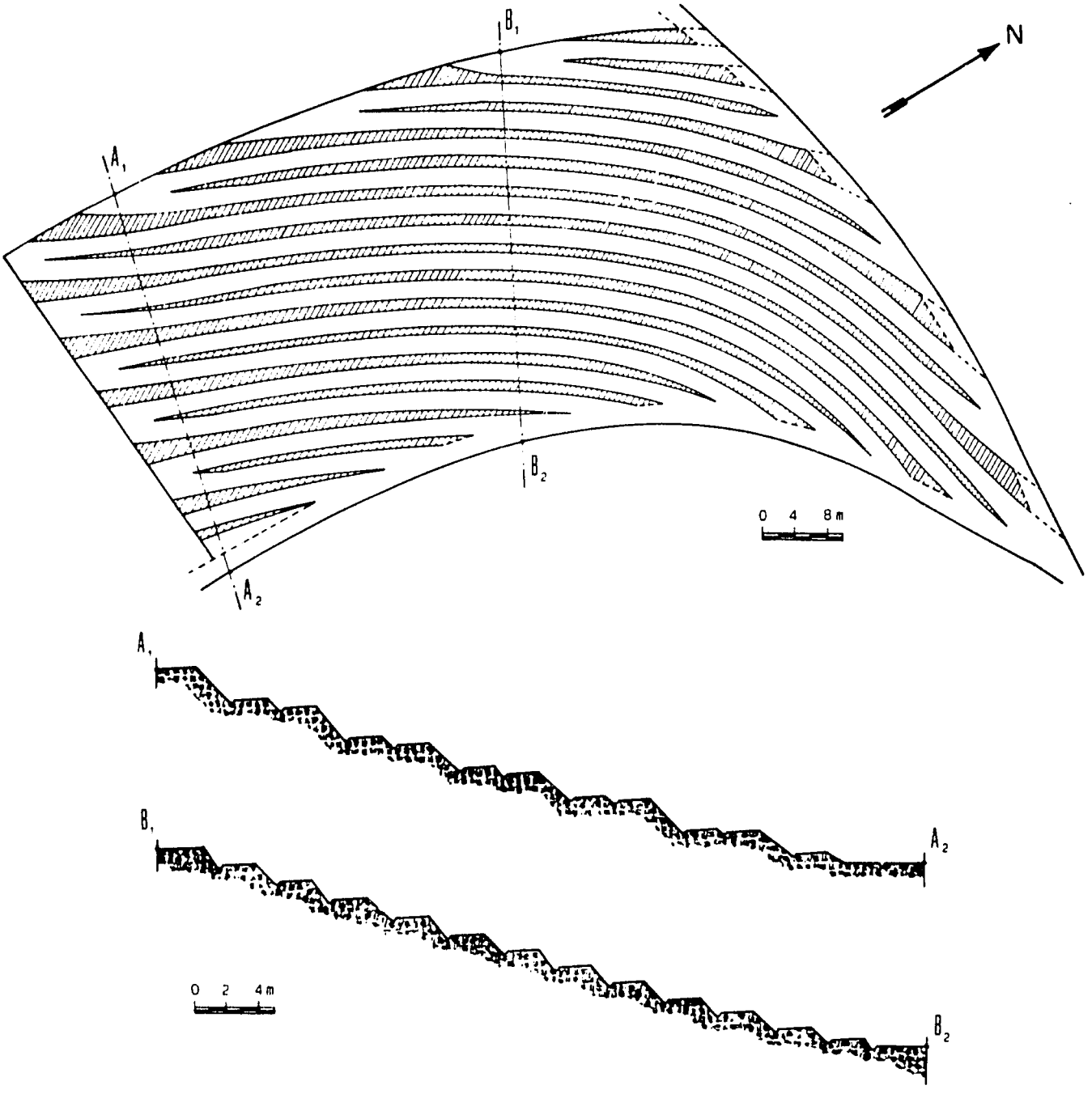

Figure 1. Orchard with narrow terraces joining two by two at the headlands into a levelled area. The average cross slope of the field is 27%. The distance between the rows is 3.5 m; the terraces, which have a slight uphill slope, are, on average, 2.40 m wide and the backslopes are 1.10 m high.

There were no land-slips during the first years even in the most critical sectors of the backslopes of the connecting areas in the steepest points (33%), where the difference in level between the two connecting areas reached 2.4 m. Only after extremely heavy and continuous rainfall and excessive backslope erosion caused by tillage operations did some land-slips occur on the backslopes.

The summer of the first year after the planting of the trees was particularly dry and the crop suffered from the high evaporation caused by the terrace construction, which created a larger evaporating area. In fact, only 70% of the plants rooted. After the plants had grown, no more damage from dry weather was recorded.

The runoff of rainwater was satisfactory even

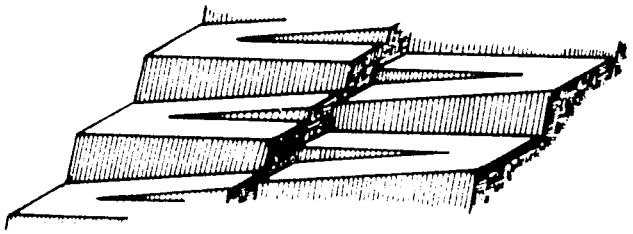

Figure 2. Detail in perspective view of the connecting areas of the terraces which join two by two.

though the furrow dug along the backslope filled with soil after a few years and was not restored owing to the limited width and length of the terrace.

The various farming operations were regularly performed and they required the same amount of time as comparable operations on flat land. The pruning and harvesting operations were easily carried out with the aid of a platform mounted on a tractor and fitted with four mobile platforms for the four-man crew.

Only the maintenance of the grass-covered backslopes presented some difficulties: an annual cutting was needed, followed by chemical weed destruction.

In 1968 the technique of narrow terraces joined at the head-lands in groups was applied to two new fields. The principles involved in this innovation, compared to the first system, are shown in Figs. 3 and 4.

One of these fields, adjoining a vineyard to be enlarged (which was planted in contoured rows, with 2 m between the rows and with a slope varying from 30% to 45%), was arranged into terraces by cutting a moderate backslope and by reducing the cross slope to 15-20% while a constant longitudinal gradient of 0.5 to 8% was created. The new rows were planted as a continuation of the preexisting ones.

Before planting the vines, turning areas involving 4 inter-rows were constructed at the ends of the rows. The outward slope was 15% and this gradually reached the original slope of the land.

With this configuration the rainwater ran off along the furrow left near the row by the various tillage implements. On the steeper slopes one of the rows of each connecting area must be shortened by a few meters where there is the backslope.

The runoff of rainwater was always regular and compared to previous conditions the use of farm machinery was easier.

In the second field, with a surface of 3.650 sq.m and a slope ranging from 10 to 32%, rows connected at one end by a turning area (Fig. 5) were laid out in order to check the farmability and the stability of the land after the terracing. At the other end of the rows connecting areas were not necessary because the slope was less than 15%.

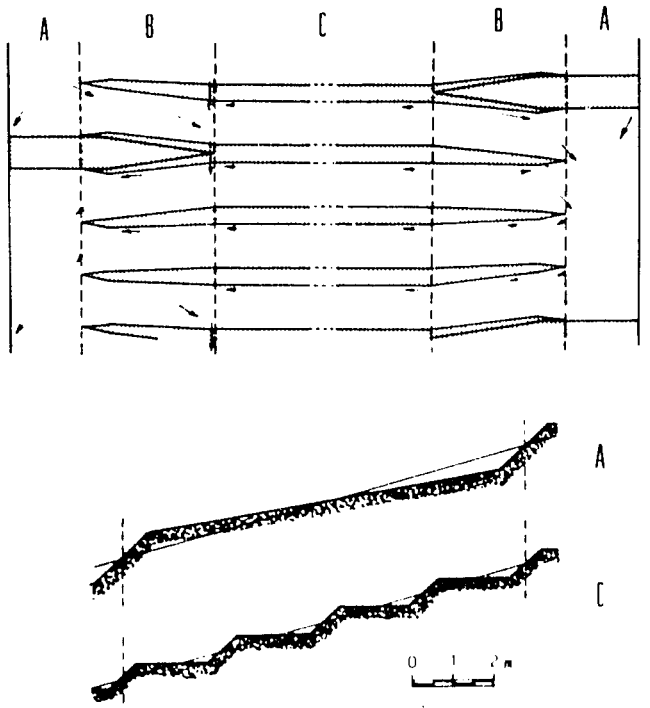

Figure 3. Schematic plan of a field with uniform cross slope, arranged in terraces connected in groups. A. Connecting areas for groups of four terraces. B. Connecting zones between these areas, single terraces and zones with original slope, the latter indicated with the letter C. (Arrows indicate the direction of the runoff in a field where the longitudinal slope of the terraces, in non-connecting zones (C), was 2%.

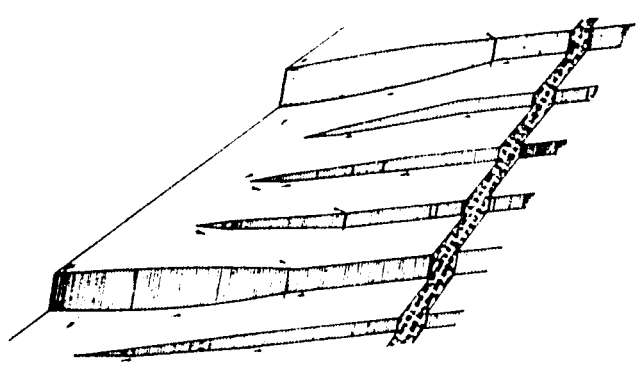

Figure 4. Detail in perspective view of a connecting area (with downward slope reduced to 15%) between a group of four terraces with a slight uphill counter-slope.

Rows lie across the slope and have a longitudinal gradient ranging from 0.5 to 13% with a 2.75 m inter-row. Near the connecting area the inter-rows become more narrow up to 2.5 m, in order to make up for the space occupied by the backslope every 4 rows. This was necessary because the backslope was constructed in proximity to the inter-row and consequently the terrace width was reduced to 2 m.

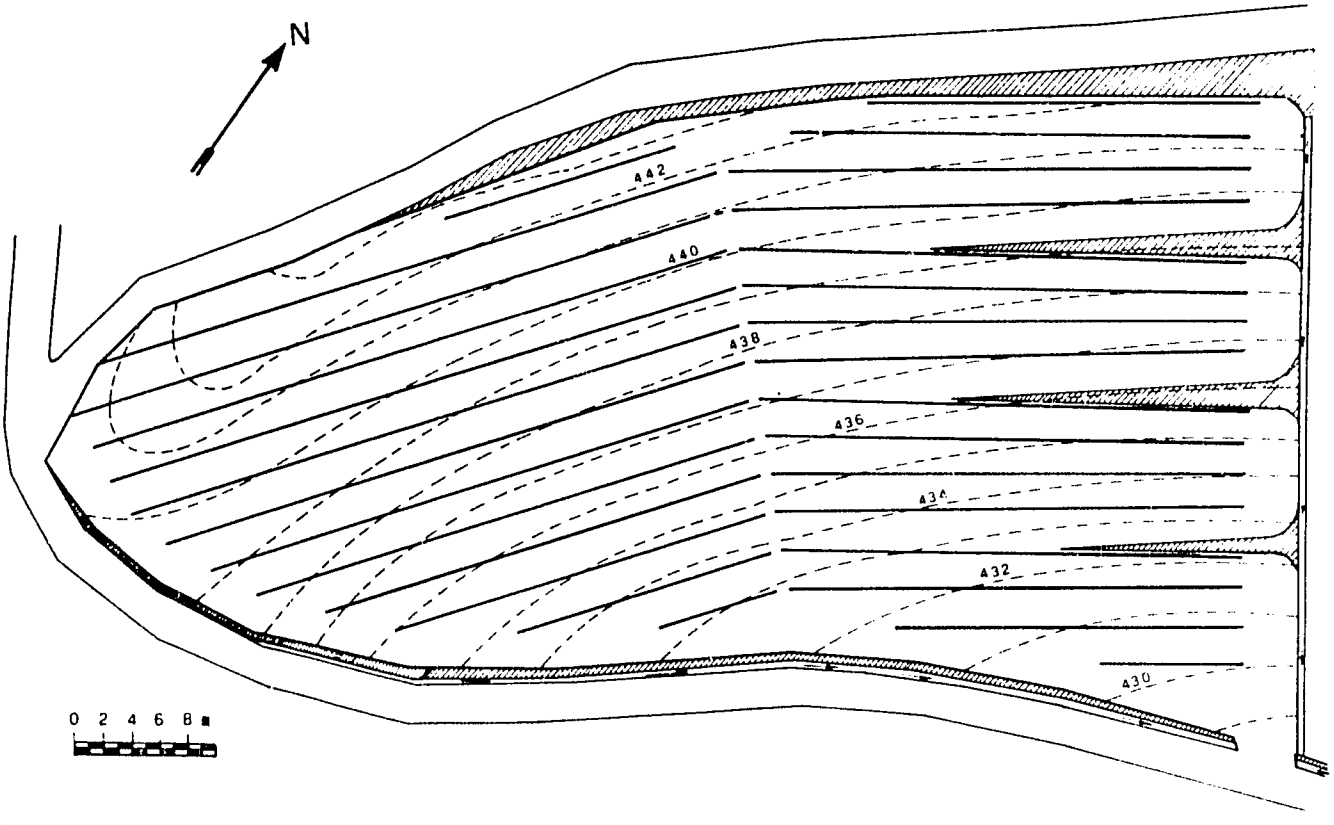

Figure 5. Vineyard with rows connected at one headland by groups of four in areas with a reduced slope. The backslope for the formation of a connecting area is placed above a row. Water runs along the inter-rows in a furrow opened during soil tillage toward the headland beyond which is a collecting ditch. The distance between the rows is 2.75 m.

The farming of the vineyard was easy except for the maintenance of the backslope near the row and the passage of machinery in the points where the inter-row was narrow.

Also, with this arrangement the original cross slope was left unchanged. It was only slightly reduced by means of a moderate backslope below the row produced by tillage operations. The discharge of rainwater along the rows in the furrow opened by tillage implements was regular, especially when the gradient was greater than 1%.

In spring 1976, a new vineyard was planted on a plot of 1.2 ha with a slope ranging from 18 to 34%. After deep plowing, the slope of the connecting area was reduced to 15% and sets of 4 rows were linked together between the connecting areas (Fig. 3). Vines were then planted in across-the-slope rows with a 3.2 m inter-row and a longitudinal gradient of between 0.5 and 12% (Fig. 6) so that the vines could be trained to the hanging curtain system which is derived from the "Duplex" system.

To follow the lay of the land the 140-m long rows were cut and "bent" approximately in the middle to form a central headland. This operation was necessary also because the number of rows was different in the two parts of the vineyard and the ends of the single half rows do not always meet, as can be seen in the figure. In fact, on the left-hand side of the vineyard there are 4 rows more than on the right-hand side, therefore the machine must turn in the central headland twice. The headland in the other parts of the field is crossed by the machines travelling the two sections of the same rows, even though their headlands do not coincide.

Also, here rainwater discharges into an across-the-slope ditch near one of the headlands.

The backslope of the connecting areas being formed in proximity to the row, the inter-row distance is unchanged and its maintenance is easier. The connecting areas link rows, four-by-four, but in a staggered way, so as to allow the farm machines, which zigzag, to pass from one area to the other.

With the above mentioned row arrangement the cross slope resulting was slightly reduced, ranging from 12 to 30%. With the tillage operations, low backslopes could be obtained near the row, further reducing the cross slope in order to ease the use of machines.

The backslopes of the connecting areas were 6 to 20 m long, depending on the ground slope.

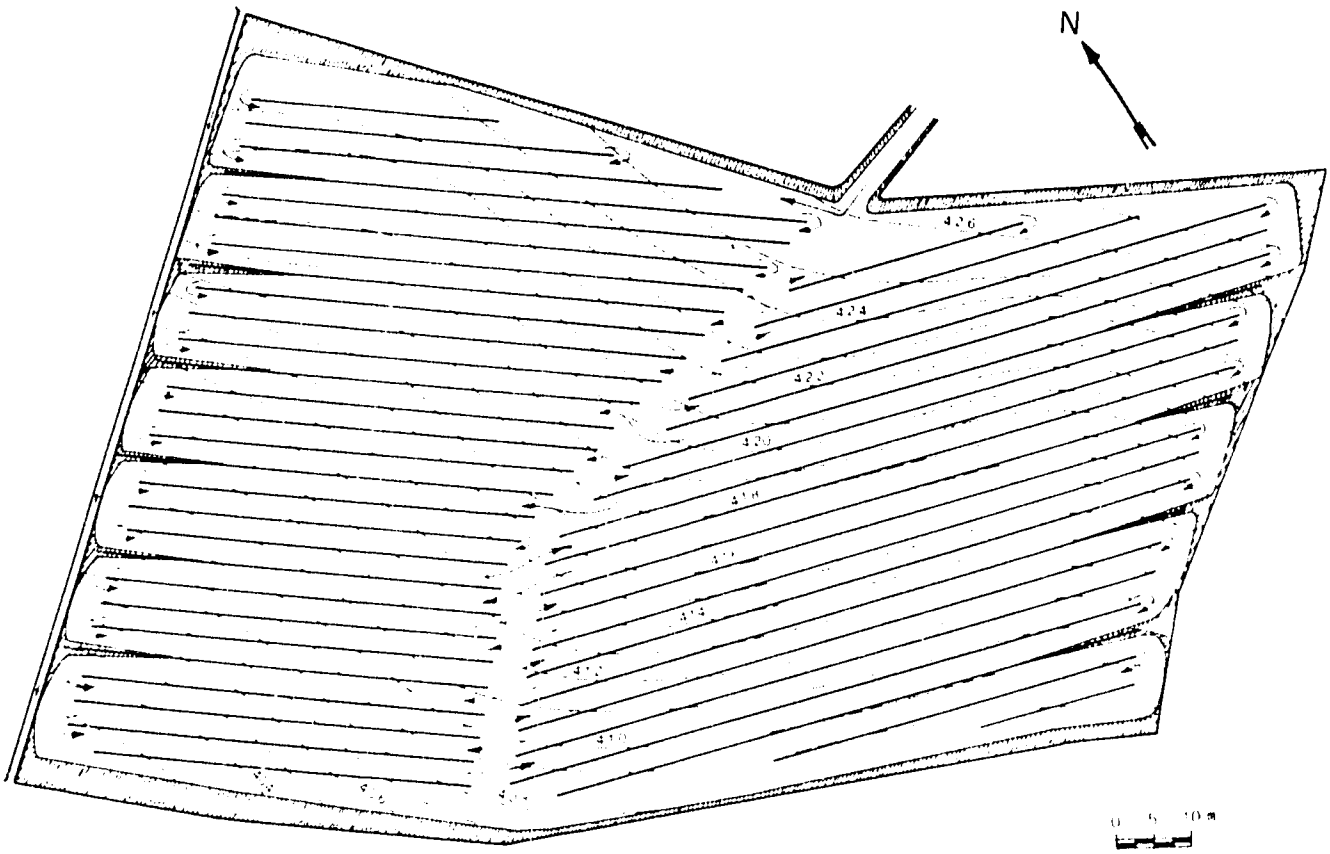

Figure 6. Vineyard with rows connected on headlands by groups of four areas with slope reduced to 15%. The backslope for the formation of connecting areas is placed in correspondence of a row. Rows have a moderate longitudinal slope and the cross slope is reduced only by a small backslope corresponding to the rows. Distance between rows is 3.25 m. Machinery travels in the way indicated by the arrows. Dotted lines represent the original contour lines of the field, which has a slope ranging from 18 to 34%.

The land arrangement was carried out with a 90-hp tractor mounted scoop in 9½ hours, i.e., 8 hours per ha.

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DISCUSSION

J. Phelan (Virginia, USA). Did you have any standards for the maximum or minimum gradients on your terrace system?

Lisa. Yes, a maximum of from 20 to 35% in these areas.

Phelan. I was thinking of the slope that you produced with the terrace.

Lisa. We have reduced the slope up to a maximum of 13% after the construction of the terrace. It is necessary to have rows longer than 100 m and, therefore, because of the variation of the land, it is necessary to vary the slope of the terrace.

D. Plucknett (Hawaii, USA). Do they still use cattle or draft animals on some of that terraced land and is there any interest in maintaining them to do some of the draft work?

Lisa. No, we have especially grape cultivation or tree cultivation and the animals can damage the plants. We use a mower one time a year, then we use pesticides for control.

Plucknett. Is that the general policy everywhere in Italy—to use the tractors and pesticides?

Lisa. It was traditionally animals, but not now.

E. J. Ravalo (Puerto Rico). I have one question regarding those terraces in your country that you

have shown on the slides: How long did it take you to complete them in machine hours per acre?

Lisa. We have eight hours per ha in this case. Eight hours is only for the rough work with machinery for doing the terraces; afterward you are cultivating the land to finish up the work. After the terraces are done the time necessary is comparable to the time needed for a deep plowing.

D. Watt (Pennsylvania, USA). Do these terraces have annual heavy rainfalls such as we have in our climate here in the summertime—heavy torrential thunderstorms?

Lisa. The terraces occasionally receive heavy storms in the summer.

72.
Cover Crops, Mulching, Grass Barriers and Grass Waterways on Hill Land Orchards

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Soil conservation is important in the development of hill land in Taiwan because of such factors as erosion, steepness of slope, high and excessive rainfall, a long dry season (October to May), and the wide range of crops grown there. All these factors contribute to a very complex problem. The results of experiments conducted indicate that conservation measures in Taiwan differ from those used in the United States and Japan.

Bench terracing was considered one of the most effective soil conservation measures in hill land farming and it was used as a major conservation practice in the past in Taiwan. But its construction cost is rather high since labor shortage became a serious problem in recent years. Also, it is not suitable to farm mechanization. Hence, it can hardly meet the requirements of modern conservation measures for farmland. The purpose of modern conservation methods is not only to reduce soil and water losses but to minimize labor cost for crop production.

Many experiments indicated that cover crops, mulching, grass barriers, and grass waterways were more effective for conservation than engineering measures such as bench terracing and brick channels.

COVER CROPS AND MULCHING

Any crop serving as a solid ground cover to control soil erosion and to improve soil productivity, whether or not specifically planted for that purpose, is a cover crop. Mulching with crop residues can effectively keep soil erosion to a minimum, add organic matter to soil, and conserve soil moisture.

In earlier studies of pineapple plot runoff, soil and water losses on reverse slope bench terraces were quite similar to the treatments of contour, close planting and straw mulching (Table 1). Maximum yield of pineapple was obtained from the same treatments (Table 2). In the fallowing season between two crop years of pineapple, stubble mulching was judged to be the ideal land use (Chang *et al.*, 1968).

Many experiments have been conducted since 1964 to find out the effects of soil and water conservation, mulching and cover crops on the hill lands of banana, citrus, and litchi plantations. Five kinds of cover crops were used: Guinea grass (*Panicum maximum*, Jacq), Centrosema (*Centrosema pubescens*, Benth), Calopogonium (*Calopogonium mucunoides*, Desv), Bahia grass (*Paspalum notatum*, Fluegge), and Indigofera (*Indigofera spicata*, Forsk). Material mowed from respective cover crops was used to mulch around the fruit trees underneath the canopies. Bahia grass had the highest effect on control of erosion (Chang, 1970; Chang and Cheng, 1974; Wang *et al.*, 1975).

A further experiment was performed on a 24% slope banana plantation with clay loam soil. Five treatments were used: drainage type level terrace; grass barrier with 2.5 m spacing; grass barrier with 5.0 m spacing; cover crop and mulching with Bahia grass; and clean-cultivation as check. Cover crop and mulching with Bahia grass had minimum runoff. From the difference of the linear regression coefficient, there was a significant ($P < .05$) difference between cover crop and mulching with Bahia grass and drainage type level terrace. The former was more effective than the latter (Fig. 1). Also, the amount of soil loss in each treatment was proportional to that of runoff. Minimum soil loss was about 0.36

TABLE 1. Runoff from each plot with different pineapple plant ages on clay loam soil with 20% slope

Age of pineapples	Treatments: Reverse[b] slope bench terrace	Contour,[c] close planting, & straw mulching	Contour[d] & close planting	Contour[e] & loose planting	Up & down,[f] loose planting as check
			mm[a]		
1 year[a]	0.0351	0.0418	0.0552	0.2401	0.3332
2 years[b]	0.0284	0.0360	0.0571	0.1304	0.2213
3 & 4 years[c]	0.0307	0.0392	0.0470	0.0875	0.1020

[a]When rainfall increased by one millimeter, the runoff of each treatment is shown. Each number has a highly significant difference level of 1%.

[a, b, c, d, e, f]Linear regression coefficients for five treatments, (1) reverse slope bench terrace, (2) contour, close planting and straw mulching, (3) contour and close planting, (4) contour and loose planting, and (5) up and down, loose planting as check, are, β_1, β_2, β_3, β_4 and β_5, respectively.

[a]$\beta_1 = \beta_2$, $\beta_1 \neq \beta_3$, $\beta_1 \neq \beta_4$, $\beta_4 = \beta_5$.

[b]$\beta_1 \neq \beta_2$, $\beta_2 \neq \beta_3$, $\beta_1 \neq \beta_4$, $\beta_4 \neq \beta_5$.

[c]$\beta_1 \neq \beta_2$, $\beta_2 = \beta_3$, $\beta_3 \neq \beta_4$, $\beta_4 = \beta_5$.

Data from Chang *et al.* (1968).

TABLE 2. Average yield of pineapple from various treatments

Yields	Treatments: Reverse slope bench terrace	Contour, close planting & straw mulching	Contour & close planting	Contour & loose planting	Up & down, loose planting as check
			MT/ha		
1st crop yield	76.045	93.016	86.131	57.509	57.512
2nd crop yield	99.235	107.746	92.075	52.643	56.226
Avg. yield	87.640	100.381	89.103	55.076	56.869
Yield increase (%)	59.13	82.26	61.78	0	8.26

Data from Chang *et al.* (1968).

MT per ha in four years from cover crop and mulching with Bahia grass (Table 3) (Wang, 1976).

Orchards in Taiwan are generally on steep land. Because of this, another trial was carried out on a 46% slope litchi plantation to see what effect cover cropping and mulching have on erosion of such steep slopes. Of four treatments used, erosion was controlled best (less water and soil losses) by cover crop and mulching with Bahia grass (Tables 4 and 5). Under this treatment water and soil losses were small even on slopes as steep as 53%.

Ten years ago, Centrosema was a major cover crop used in the hill land banana plantations due to its thick cover and nitrogen fixation. However, its climbing habit needed more management than other crops. Further, extracts from its roots, stem, and leaf possessed the highest p-hydroxybenzoic and vanillic acid levels among many kinds of cover crops. This toxicity caused poor growth of banana. Bahia grass had the least toxic effect compared to Indigofera and Centrosema (Wu *et al.*, 1975).

In recent years the author and his colleagues have emphasized study oi the relationship between cover crop and mulching with Bahia grass and soil physicochemical properties in order to find out proper soil management measures.

Although Bahia grass had desirable agronomic characteristics which reduced soil and water losses, its daily water consumption during the period of vigorous growth (August to September at Fengshan) was as much as 14 mm/day. In this season, grass must be cut in order to reduce the evapotranspiration rate. The water consumption decreased by 30% after cutting, which lessened competition with main crops for soil moisture (Chang and Tsai, 1974).

Bahia grass can be grown within a wide range of pH values. Its growth was normal on soils with pH within the 5.5–8.9 range; best results were achieved on soils with pH level within 5.5–7.9 (Chang and Tsai, 1973).

Bahia grass tolerates shade. Levels of sunlight intensity at 40% to 60% were most suitable for growth and produced high yields of grass and hay (Hsi and Chang, 1971).

TABLE 3. Soil loss from different treatments

Year of measurement	Drainage type level terrace	Grass barrier with 2.5-m spacing	Grass barrier with 5.0-m spacing	Cover crop & mulching with Bahia	Clean-cultivated as check
	Treatments				
			MT/ha		
1971	0.192	1.262	4.463	slight	21.702
1972	0.207	1.926	6.115	0.174	38.510
1973	0.129	0.965	3.230	0.118	25.453
1974	0.084	0.416	1.938	0.072	71.819
Total	0.612	4.569	15.746	0.364	157.484
Mean	0.153	1.142	3.936	0.091	39.371

Data from Wang (1976).

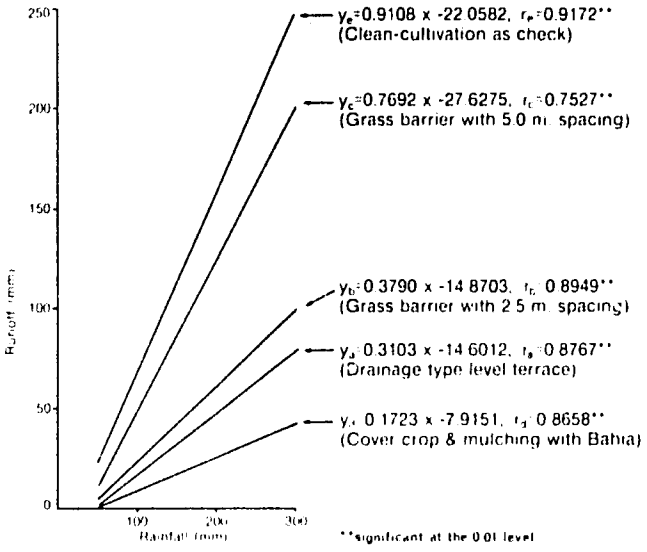

Figure 1. Linear regression of runoff vs rainfall under bananas on a 24% slope. Each regression coefficient has a highly significant difference level of 1%. The results of tested linear regression coefficients are as follows: $\beta_d \neq \beta_a$, $\beta_a \neq \beta_b$, $\beta_b \neq \beta_c$, and $\beta_c \neq \beta_a$. From Wang (1976).

TABLE 4. Runoff per mm rainfall from different treatments under litchi on 46% slope

Cover crop & mulching with *Desmodium buergeri*	Cover crop & mulching with Bahia grass	Clean-cultivated as check	Mulching with Weeping love grass
Treatments			
		mm	
0.1569	0.0123	0.5406	0.1748

Each number shows a significant difference of up to 1%. Linear regression coefficients for four treatments, (1) cover crop and mulching with *Desmodium buergeri*, (2) cover crop and mulching with Bahia grass, (3) clean-cultivated as check, and (4) mulching with Weeping love grass are β_a, β_b, β_c and β_d, respectively. $\beta_b \neq \beta_a$, $\beta_b \neq \beta_d$, $\beta_b \neq \beta_c$, $\beta_d \neq \beta_a$, $\beta_d \neq \beta_c$ and $\beta_a \neq \beta_c$.
Data from Wang *et al.* (1975).

TABLE 5. Summary of soil loss from different treatments under litchi on 46% slope

Year of measurement	Cover crop & mulching with Desmodium buergeri	Cover crop & mulching with Bahia grass	Clean-cultivated as check	Mulching with Weeping love grass
	Treatments			
		MT/ha		
1971	5.7576	0.5260	49.1329	0.8235
1972	2.2278	0.0533	85.8994	2.9053
1973	0.8119	0.2020	50.8227	1.1928
1974	1.6490	0.0415	33.4201	2.9975
Total	10.4463	0.8228	219.2751	7.9191
Mean	2.6115	0.2057	54.8187	1.9797

Data from Wang *et al.* (1975).

After one year's growth, the root system distribution of Bahia grass (A 44 variety) penetrated as deep as 59 cm into the soil (Wang, 1973).

The organic matter content of the surface soil was increased from 0.9% to 2.4% after Bahia grass was planted as cover crop for six years (Wang, 1976).

Soil covered with Bahia grass had the highest hydraulic conductivity—5.15×10^{-2} cm/min; the least was obtained from drainage type level bench terrace—7.59×10^{-4} cm/min. Hydraulic conductivity increased after grasses had been planted on hill land orchard for a long period. Soil aeration and water permeability were also improved (Wang, 1975).

As stated above, although cover crop and mulching with Bahia grass was the most effective treatment, its competition with main crops for nutrients and water was still high. A modified measure, alternate strips of cover crop and mulching with Bahia grass, was used in juvenile orange and mango plantations in an effort to keep such competition at a minimum. The fruit yields obtained under this treatment were higher than yields from the complete cover and mulching treatment. However, the surface runoff between the two treatments was not significantly different. (Liao and Chang, 1974; Wang, 1976).

GRASS BARRIERS

Close planting of at least two rows of grasses to trap silt according to planned vertical intervals would form bench terraces. It also would reduce the slope, thus facilitating mechanical operations.

Experiments conducted by the author to find the rate of slope reduction, the amount of soil and water losses, the proper kinds of grasses, and the appropriate grass barrier spacing are summarized as follows:

According to the function of grass barriers on a 23% slope banana plantation with clay loam soil, Weeping love grass (*Eragrostis curvula*, Nees) barrier with mulching had the minimum runoff and soil loss, and the highest fruit yield (Tables 6, 7 and 8). Slope reduction within three years was from 11.5% to 7%, i.e., the original slope of 23% was decreased from 11.5% to 16%. The rate of slope reduction depended on the factors of rainfall, soil texture, field management, and availability of mulching (Wang, 1970).

Three kinds of vegetation, Day-lily, Guinea grass, and Bahia grass, were used to establish barriers with spacing of 2.5 m and 5.0 m, respectively. The yields of bananas from the barriers of the three kinds of vegetation showed no difference, but the banana yield of the 5.0 m Bahia grass barrier was significantly higher due to less competition for nutrients and soil moisture. The interaction between kinds of vegetation and the spacing was significant (Wang *et al.*, 1971).

Slope reduction was significantly different among the kinds of vegetation and spacing. The Bahia grass barrier with 2.5-m spacing had the best effect in reduction of slope (Wang *et al.*, 1971).

From the interaction between the kinds of vegetation and spacing, the Bahia grass barrier with 5.0-m spacing was very desirable since larger spacing facilitated the farming operation (Wang, Liao, and Chang, 1971). However, the spacing between two grass (or vegetative) barriers, if not more than 8 m apart, would trap silt and reduce the slope, facilitating mechanical operations (Wang *et al.*, 1974).

GRASS WATERWAYS

Grass waterways are natural or man-made water courses protected against erosion by a grass cover. They serve as safe outlets for terraces, diversions, cover crop, and mulching with hillside ditches, and contour rows. Good grass waterways are a must in controlling erosion on farms. A grass waterway with a dense, vigorous growth of grass is needed to carry a flow of water with least erosion.

TABLE 6. Runoff per mm rainfall from different treatments under banana on 23% slope

Treatments						
Guinea[a] grass barrier with mulching	Guinea[a] grass barrier without mulching	South[a] African pigeon grass barrier with mulching	Weeping[a] love grass barrier with mulching	Weeping[a] love grass barrier without mulching	Reverse[a] slope bench terrace without topsoil	Clean-[a] cultivated as check
			mm[b]			
0.395	0.478	0.486	0.368	0.489	0.283	0.534

[a]Linear regression coefficients for seven treatments, (1) Guinea grass barrier with mulching, (2) Guinea grass barrier without mulching, (3) South African pigeon grass barrier with mulching, (4) Weeping love grass barrier with mulching, (5) Weeping love grass barrier without mulching, (6) reverse slope bench terrace without topsoil, and (7) clean-cultivated as check are β_a, β_b, β_c, β_d, β_e, β_f, and β_g, respectively. $\beta_f = \beta_d$, $\beta_f \neq \beta_a$, $\beta_d = \beta_a$, $\beta_d = \beta_c$, $\beta_d = \beta_e$, $\beta_d = \beta_b$, $\beta_d \neq \beta_g$, $\beta_a = \beta_c$, $\beta_a = \beta_e$, $\beta_a = \beta_b$, $\beta_a \neq \beta_g$, $\beta_c = \beta_e$, $\beta_c = \beta_b$, $\beta_c = \beta_g$, $\beta_e = \beta_b$, $\beta_e = \beta_g$, and $\beta_b = \beta_g$.

[b]Each number has a highly significant difference level of 1%.

TABLE 7. Summary of soil loss from different treatments under banana on 23% slope

Year of measurement	Treatments: Guinea grass barrier with mulching	Guinea grass barrier without mulching	South African pigeon grass barrier with mulching	Weeping love grass barrier with mulching	Weeping love grass barrier without mulching	Reverse slope bench terrace without topsoil	Clean-cultivated as check
				MT/ha			
1966	4.008	10.361	3.466	3.288	5.760	1.439	83.220
1967	0.764	9.367	0.975	0.711	1.645	0.332	73.814
1968	0.544	5.005	1.026	2.776	1.689	0.254	34.648
Total	5.316	24.733	5.467	4.775	9.094	2.025	191.082
Mean	1.772	8.244	1.822	1.591	3.031	0.675	63.694

Data from Wang *et al.* (1970).

TABLE 8. Banana yield from different treatments on 23% slope

Yields	Treatments: Guinea grass barrier with mulching	Guinea grass barrier without mulching	South African pigeon grass barrier with mulching	Weeping love grass barrier with mulching	Weeping love grass barrier without mulching	Reverse slope bench terrace without topsoil	Clean-cultivated as check
				MT/ha			
Average	10.07	8.98	9.47	10.56	9.21	9.50	8.19
				%			
Yield increase (%)	22.86	9.64	15.54	28.84	12.37	15.95	0

Data from Wang *et al.* (1970).

In order to meet the requirements of steep slope and small flow capacity in Taiwan, a waterway planted with *Paspalum* sp. or Bahia grass (USA variety) was designed with 1.0–1.5 m top width in parabolic cross section with 50 cm depth. That was enough to carry the capacity of 0.026–0.067 m^3/sec on 30% to 50% slope for the duration of 72 hours. The maximum flowing velocity was 3.0 m/sec (Liao *et al.*, 1970; Wang, 1976).

Taiwan's existing economic structure necessitates the development of industry. Labor-saving measures must be considered first in hill land development. Research in possibilities of adopting more agronomic measures which cost less and are equally effective in the utilization of hill land should be emphasized and strengthened.

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73.
Effects of Bench Terrace and Improved Hillside Ditch

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Soil conservation problems in Taiwan are conspicuous since Taiwan is an island with high intensity rainfall, a long dry season, erodible soils on steep hill lands and diversified crops which contribute greatly to the seriousness and complexity of the problem.

The soil conservation program in Taiwan started in 1952. All the measures taken in the past were designed by experts without support from experimental data (Landon, 1963). Therefore, the author began studies of soil conservation measures, initially emphasizing two major items: bench terracing and hillside ditching, in addition to soil conservation experiments on sugarcane and pineapple farms and on citrus orchards.

The results are summarized as follows:

BENCH TERRACES

Bench terraces have been considered one of the most effective soil conservation measures on steep hill lands. Yet, their value needs to be reconsidered (Liao, 1972).

Soil and Water Losses. In the earlier observations on sugarcane, with a 12% slope and clay loam soil, and pineapple, with a 20% slope and clay loam soil, runoff plots without outlets, the soil and water losses on reverse slope bench terraces were less than those of hillside ditches combined with agronomic measures. Later, when outlets were built in conformity with field practice, the runoff increased sharply from the past (2.93% to 26.05%) which was much higher than that from the close-planting and mulched plots (Chang *et al.*, 1968).

Further observations were made in litchi plantations—a 36% slope, clay loam soil, and a large area—to compare runoff between reverse slope bench terraces and hillside ditches. Runoff from the bench terrace was higher than that of the hillside ditch in the first year and reduced gradually in later years (Tables 1-4; Liao *et al.*, 1970; Liao *et al.*, 1974).

The experiment on a 28% slope banana plantation with clay loam soil had seven treatments with three replicates. The seven treatments were reverse slope bench terraces with and without topsoil re-topping, level bench terraces with and without topsoil re-topping, grass barriers, individual basins and clean-cultivation. Every treatment with a water tank on the bottom of the first replicate was used for the observation of soil and water losses. Runoff from the level bench terrace was lower than from the reverse slope bench terraces and other treatments. The same is true for soil loss. The level bench terraces had the lowest soil loss, 3 tons/ha/year, and the clean-cultivated the highest at 277 tons/ha/year. In conserving soil moisture, the level bench terrace was more effective and the significant difference was found among them. But considering the higher construction cost of the level bench terrace, its economic value is a matter of question (Liao *et al.*, 1969).

In recent experiments on banana and citrus

TABLE 1. Comparison of runoff in 1967 and 1970

Dates of measurement	Rainfall	Treatments: Bench terrace Runoff	Bench terrace Peak flow	Hillside ditch Runoff	Hillside ditch Peak flow
1967			*mm*[a]		
May 24	127.5	55.38	0.05836	55.98	0.06419
May 25	5.5	2.39	0.02682	1.63	0.02280
May 26	20.0	8.80	0.03047	6.12	0.01688
Jun. 2	87.0	39.50	0.04160	36.21	0.03579
Jun. 11	72.5	36.57	0.03834	26.29	0.03084
Jun. 12	15.0	5.44	0.01042	2.04	0.00382
Aug. 30	9.0	3.76	0.00501	3.73	0.00629
Sep. 7	46.3	25.37	0.03794	16.00	0.05480
Total	382.8	177.21		148.00	
Runoff (%)		46.29		39.66	
1970			*mm*[a]		
Jul. 9	42.6	7.22	0.00246	11.82	0.01082
Aug. 14	57.0	12.57	0.00586	15.42	0.00903
Aug. 18	32.0	2.56	0.00411	4.17	0.00501
Aug. 21	37.0	7.14	0.01042	10.35	0.01121
Aug. 22	16.0	2.21	0.00382	2.69	0.00855
Sep. 5	66.6	17.14	0.02843	19.20	0.02840
Sep. 7	21.5	2.44	0.00351	3.59	0.00201
Sep. 8	130.5	24.06	0.01303	32.45	0.01637
Total	402.7	75.34		99.69	
Runoff (%)		18.71		24.76	

[a]When rainfall increased by one millimeter, the runoff of each treatment is shown. Data from Liao *et al.* (1970).

TABLE 2. t-test of runoff between the hillside ditch and the reverse slope bench terrace in 1967 and 1970

Years	Calculated t-value	Tabulated to .05
1967	2.523	2.365
1970	3.424	2.365

Data from Liao *et al.* (1970).

plantations, runoff and soil losses from cover crop and mulching treatments were close to those from level bench terraces and even lower than those from other treatments (Fig. 1 and Tables 5 and 6) (Liao and Chang, 1974; Wang, 1976). With regard to soil moisture content, the observations on a citrus orchard revealed that the level bench terraces had a higher soil moisture content which was close to those of strip cover crop and mulching treatments. The soil moisture p^F curve* of the latter treatment was slower than on other types of bench terraces (Liao and Chang, 1974).

As stated above, the soil conservation effect of all types of bench terraces was poorer than that of Bahia grass and mulching (except level retention terraces). For this reason, it is advisable to reconsider bench terracing on steep hill lands (Liao, 1972).

On Crop Yield. From observations of soil and water losses on sugarcane, with a 12% slope and clay loam soil, and pineapple, with a 20% slope and clay loam soil, runoff plots, bench terraces gave lower crop yield than contour and close planting and mulching (Chang *et al.*, 1968; Liao, 1972). The same was true in the field experiments. This crop yield tendency is in conformity with the result of observations on a tea plantation (Lin, 1969).

From the experiment on comparison of level bench terraces with agronomic practices now under way,

*The logarithm of suction head is employed (p^F).

TABLE 3. Comparison of runoff in 1971 and 1974

Dates of measurement	Rainfall	Treatments: Bench terrace Runoff	Bench terrace Peak flow	Hillside ditch Runoff	Hillside ditch Peak flow
			mm[a]		
1971					
July 6	27.8	8.03	0.001412	8.15	0.004572
July 10	25.4	1.17	0.000143	2.09	0.004971
July 27	179.0	35.16	0.014331	58.58	0.027739
Aug. 4	87.2	41.80	0.015928	25.47	0.009516
Aug. 8	14.8	2.68	0.002313	2.24	0.001058
Aug. 11	47.0	11.78	0.002313	14.14	0.004192
Aug. 26	47.0	12.88	0.010123	10.80	0.010123
Sep. 13	15.0	4.50	0.000261	3.46	0.001412
Sep. 20	21.8	5.95	0.004572	5.84	0.004971
Total	465.0	123.95		130.77	
Runoff (%)		26.66		28.12	
1974					
Jun. 1	31.5	11.85	0.004971	5.83	0.021343
Jun. 3	182.0	16.42	0.001228	8.81	0.001412
Jun. 4	55.0	2.22	0.001056	0.54	0.001412
Jun. 19	195.5	26.36	0.002313	23.50	0.002866
Jun. 23	36.5	11.68	0.001613	1.45	0.000064
Jul. 6	100.0	16.32	0.001412	3.27	0.001412
Jul. 14	45.0	11.25	0.001613	2.60	0.001829
Aug. 24	207.5	25.12	0.003169	20.40	0.003832
Aug. 28	136.0	12.48	0.000337	6.43	0.000099
Sep. 2	242.5	36.59	0.001058	11.49	0.000763
Sep. 3	104.0	12.97	0.001058	4.45	0.000197
Sep. 9	30.5	4.57	0.001058	1.67	0.003491
Total	1,366.0	187.83		90.44	
Runoff (%)		13.75		6.62	

[a]When rainfall increased by one millimeter, the runoff of each treatment is shown. Data from Liao *et al.* (1974).

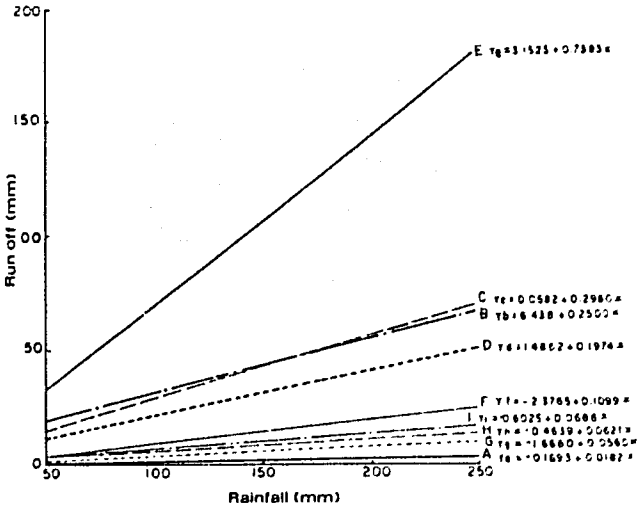

Figure 1. Linear regression of runoff vs rainfall (Every regression coefficient was highly significant. The difference between two coefficients was summarized as follows: $\beta_a = \beta_g$, $\beta_a = \beta_h$, $\beta_a = \beta_i$, $\beta_a \neq \beta_f$, $\beta_a \neq \beta_h$, $\beta_g = \beta_h$, $\beta_g = \beta_i$, $\beta_g = \beta_f$, $\beta_g \neq \beta_d$, $\beta_h = \beta_i$, $\beta_h = \beta_f$, $\beta_h \neq \beta_d$, $\beta_i = \beta_f$, $\beta_i \neq \beta_d$, $\beta_f \neq \beta_d$, $\beta_d = \beta_b$, $\beta_d = \beta_c$, $\beta_d \neq \beta_a$, $\beta_b = \beta_c$, $\beta_b \neq \beta_a$, and $\beta_c \neq \beta_a$). Data from Liao and Chang (1974).

A = Level retention terrace; *B* = Reverse slope terrace;
C = Outward slope terrace; *D* = Drainage level terrace;
E = Clean cultivation; *F* = Bahia grass cover after deep tillage;
G = Mulching with Weeping love grass;
H = Strip cover crop and mulching with Bahia grass
I = Cover and mulching with Bahia grass

TABLE 4. t-test of runoff between the hillside ditch and the reverse slope bench terrace combined with agronomic measures in 1971 and 1974

Years	Calculated t-value	Tabulated to .01
1971	0.2243	3.355
1974	4.4737	3.106

Data from Liao *et al.* (1974).

preliminary results show that a cover crop of Bahia grass has a better effect, especially in reducing soil loss. With no difference of banana yield among the treatments, the Bahia grass cover is considered to be a desirable practice (Wang, 1976).

Reclassification of Bench Terrace Types. The effect of bench terraces varies with type. Adoption of the proper type is important, as cost and effect vary with the different types.

In the past, the bench terraces were classified as level, outward slope, and reverse slope. The author has reclassified the level type into a water retention type and a drainage type and the outward slope type into a heel drainage type and a toe drainage type. Such a classification of bench terraces could meet actual requirements under diversified conditions (Fig. 2 and Tables 5 and 6) (Liao, 1972; Liao and Chang, 1974).

IMPROVEMENT OF HILLSIDE DITCHES

According to the *National Handbook of Soil Conservation Practices*, published by the U.S. Soil Conservation Service (1970), a hillside ditch of trapezoidal-shape has been used for a long time; it is referred to here as an A-section type (Fig. 3). The author adopted this A-section type in 1956 on sugarcane land but it gave reduced yield. This might be due to the fact that no sugarcane was planted on the ditch; its levee area compared with the yield from broad bottom type in subsequent years. After large-scale field observations and hydraulic tests for comparison (Mao, 1969), the broad-bottom hillside ditch, referred to here as B-section type (Fig. 4), was put into extension beginning in 1964. In Taiwan now nearly 35 000 ha of crops on hill lands have this type of broad-bottom hillside ditch combined with agronomic practices.

Multiple benefits of B-section type hillside ditches were exhibited in the observation on sugarcane plantations. In comparison of the two types, each with a plot of 0.5 ha, the yield of two ratoon sugarcane crops of B-section type is 7 to 10% higher than that of A-section type since the ditch bottom of B-section type can be used for planting and thus increases the number of plants. In addition to holding more soil moisture, the B-section type is much more stable than the A-section type and has less ditch soil erosion. The B-section type needs more cut and fill in the construction while the A-section type needs more labor to build to shape, and more maintenance. The B-section type can be constructed more easily

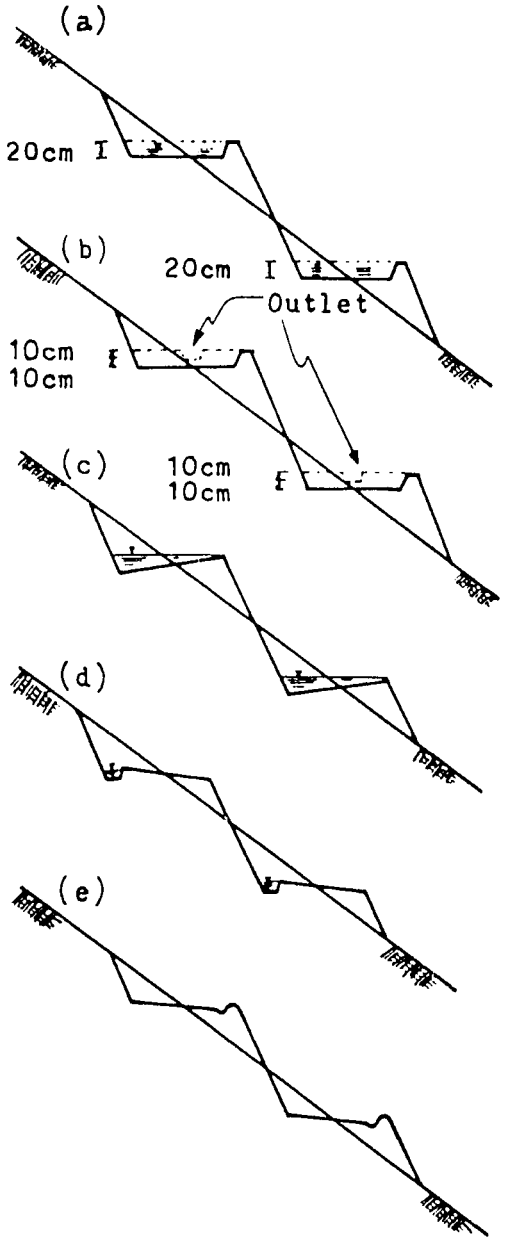

Figure 2. Types of bench terrace.
(a) Retention level type
(b) Drainage level type
(c) Reverse slope type
(d) Outward slope and heel drainage type
(e) Outward slope and toe drainage type

with a bulldozer while the A-section type can only be constructed by manual labor. Furthermore, the B-section type enables passage of small and medium size farm machinery and can be used as a farm road, which is basic to the modern hill land farm (Liao and Chang, 1971).

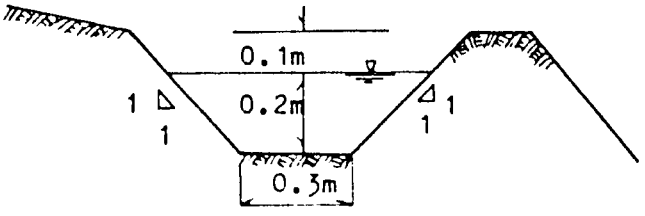

Figure 3. Cross section of trapezoidal-shape type (A-cross section).

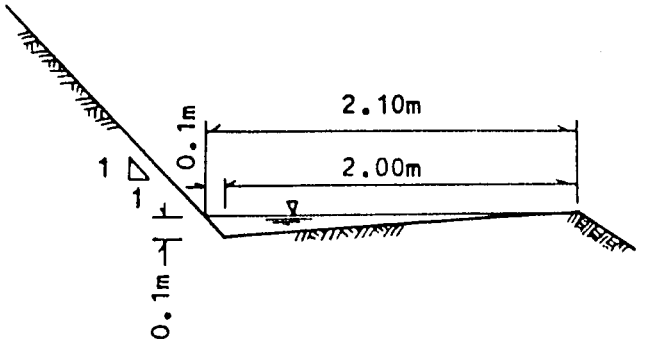

Figure 4. Cross section of broad-bottom type (B-cross section).

TABLE 5. Soil loss from different treatments on a 28% slope citrus orchard with clay loam soil

	Treatments								
	Level retention terrace	Reverse slope terrace	Outward slope terrace	Drainage level terrace	Clean cultivation	Bahia grass cover after deep tillage	Mulching with Weeping love grass	Strip cover crop & mulching with Bahia grass	Cover & mulching with Bahia grass
Year					*MT/ha*				
1971	0.000	11.199	9.820	10.509	226.550	7.138	0.000	11.240	3.774
1972	0.000	15.332	10.974	4.747	230.712	0.156	0.000	0.000	0.000
1973	0.000	2.821	3.372	2.293	81.600	0.070	0.000	0.000	0.000
1974	0.000	3.144	1.994	3.041	86.731	0.000	0.000	0.000	0.000
Total	0.000	32.466	26.160	20.590	625.593	7.364	0.000	11.240	3.774

Data from Liao and Chang (1974).

TABLE 6. Runoff from different treatments on a 28% slope citrus orchard with clay loam soil

Treatments								
Level retention terrace	Reverse slope terrace	Outward slope terrace	Drainage level terrace	Clean cultivation	Bahia grass cover after deep tillage	Mulching with Weeping love grass	Strip cover crop & mulching with Bahia grass	Cover & mulching with Bahia grass
0.0182	0.2500	0.2960	0.1974	0.7383	0.1099	0.0560	0.0621	0.0686

*When rainfall increased by one millimeter, the runoff of each treatment is shown. Data from Liao and Chang (1974).

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74.

Farmability Evaluation of Broadbase and Grassed Backslope Terrace Systems*

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The basic terrace design recommendations developed by Ramser as a result of his study of existing terrace systems in 1915 in the southeastern part of the United States are in use today (Ramser, 1945). The USDA terracing recommendations were modified in 1931 as a result of new data collected from experiments on the ten original USDA soil and water conservation experiment stations (Ramser, 1945). Additional terrace design modifications of the basic criteria were made for local conditions. Generally, the broadbase terrace systems staked in the field today follow the basic recommendations developed by Ramser.

Recently the public awareness of environmental quality and technological advances in farm machinery, earth movement, and farm management have served as a basis for change in conservation systems to satisfy the needs of present-day agriculture. Terraces require a detention storage capacity and controlled runoff release rate for row cropped land to reduce the sediment content of runoff water to acceptable levels. Farm operators recommend that, if possible, all rows be made parallel to facilitate efficient machinery operations on the sloping land. The new conservation systems cost more to install so crop production and economic returns must be maximized by reducing the low return from grassed areas to a minimum.

The grassed backslope terrace systems with tile outlets are effective as a method of sediment reduction in runoff water (Phillips, 1966). Research at Nebraska (Owen, 1969) and Iowa (Laflen, 1971) indicates that the sediment concentration in runoff water is reduced 95% with grassed backslope terrace systems with tile outlets compared to the sediment concentration in runoff from fields farmed up-and-down hill with no installed conservation practices.

Agricultural production is very competitive so field machine time and labor must be reduced to

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a minimum to compete economically. Progressive farmers producing corn and grain sorghum spend less than 4.94 hr/ha field time annually to produce a crop (Wittmuss, 1969).

Conservation systems must be planned parallel to reduce field machine time input to a minimum. Nonparallel areas in terraced fields require more time to farm and may reduce crop yields as a result of soil compaction or missed and double coverage of fertilizer or herbicides. Many farm operators have reorganized their conservation systems by making all terraces and rows parallel or removing the terrace systems and farming parallel to field boundaries. The best solution for the conservation of our water resources is to install paralleled terrace systems if the systems can be installed economically without reducing productivity.

The objective of this study was to evaluate the percentage of parallel row crop area and grassed area for different methods of terrace layout and construction. Finally, the best conservation systems and design procedures will be evaluated for use in present-day agriculture.

PROCEDURE

The study was made in two parts and two periods in time. The first was a study made near Lincoln, Nebraska, of five broadbase terrace systems installed in the Missouri Valley loessal hills in 1949 with slopes ranging from 2 to 10% (Wittmuss, 1950). Five terraced fields were selected and each terrace system was plotted on a map (Fig. 1) and analyzed (Table 1, column 2). The terrace systems were analyzed for the following: total field area, terraced area, percent parallel area, percent nonparallel area, percent grassed waterway area, percent grassed backslope, and terrace length per ha protected (Table 1).

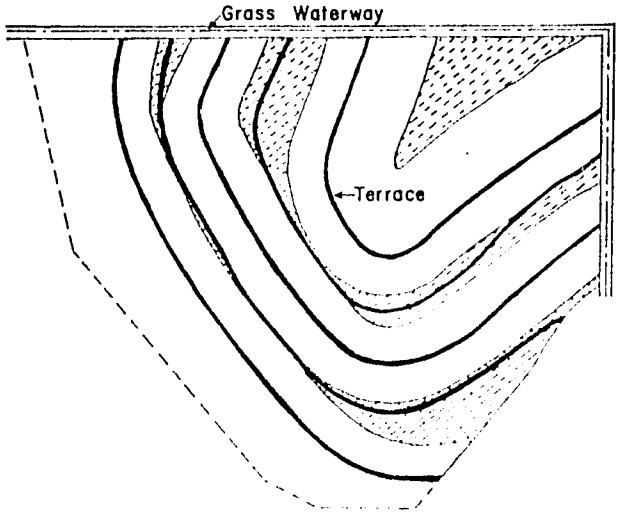

Figure 1. Field No. 1. Installed broadbase terrace system—field area, 6.4 ha; terraced area, 5.2 ha; nonparallel area, 17.6%; terrace length, 323.0 m/ha.

A stadia azimuth survey using 30.5 meter intervals and a topographic map were made of each of the five fields studied. A revised broadbase terrace system was planned on each topographic map with the objective of planning the best parallel terrace system with no lateral soil movement (Fig. 2). Each terrace system was analyzed applying the same criteria used for the original systems (Table 1).

The second part of the study was conducted from 1966 to 1970. A 130-ha farm referred to as the Rogers Memorial Farm located 16 km east of Lincoln, Nebraska (40° 50' N, 96° 30' W), was used for the

TABLE 1. Analysis of broadbase and grassed backslope terrace systems in the Missouri Valley loessal hills, Lincoln, Nebraska

	Broadbase terraces with grassed waterways		Paralleled[b] grassed backslope terraces	
	Nonparalled	Paralleled[a]	Grassed waterway	Underground waterway
Field area (ha)				
Total field	15.2	20.0	7.6	11.2
Terraced area	12.3	17.8	7.5	9.6
Grassed area (%) of terraced area waterways	9.7	9.9	4.2	
Grassed backslopes			2.9	3.1
Parallel area (%) of terraced area	75.8	82.6	98.9	98.0
Nonparallel area (%) of terraced area	24.2	17.4	1.1	2.0
Terrace length (m/ha)	309.5	279.4	237.9	183.8
Number of fields	9	5	1	3

[a]No lateral soil movement.
[b]Lateral soil movement required.

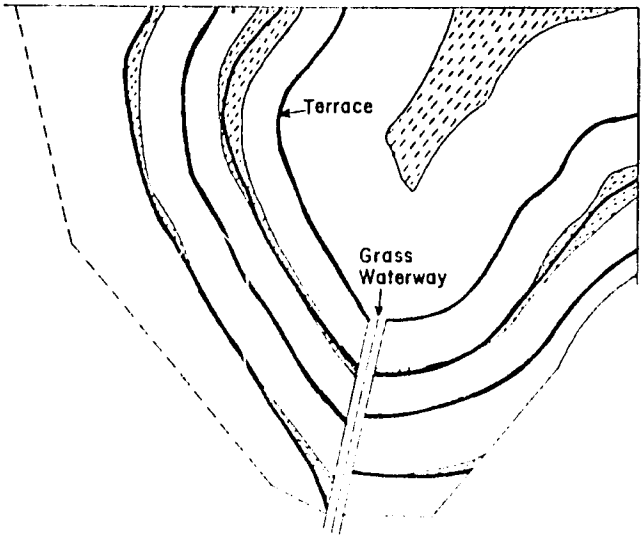

Figure 2. Field No. 1. Paralleled broadbase terrace system planned on topographic map with no lateral soil movement—field area, 6.4 ha; terraced area, 5.3 ha; nonparallel area, 12.0%; terrace length, 289.1 m/ha.

study. The farmed area under study was broken into four separate watersheds with broadbase terrace systems installed. Aerial photography and stereoplotting (Gockowski, 1970) was used to make the topographic map with 0.3 m contour intervals. The four existing broadbase terrace systems installed in the late 1940's were mapped and analyzed applying the same criteria used for the other terrace systems (Table 1).

One grassed backslope terrace system with tile outlets or grassed waterways was installed in each of the four years—1966, 1967, 1968, and 1970. The grassed backslope terrace systems were planned on the topographic map, located on the field, and constructed. Terraces were planned to be as parallel as possible; lateral soil movement was used as required. Three grassed backslope terrace systems were constructed with tile outlets with controlled runoff and 5 cm storage capacity. The other grassed backslope terrace system was constructed with a grassed waterway. The four terrace systems were analyzed using the same criteria used for the other terrace systems (Table 1, columns 3 and 4) (Figs. 3,4,5, and 6). Definition of terms:

Total field area—all of the cropable area within the field boundary.

Terraced area—all of the cropable area above the bottom terrace.

Grassed area—the cropped areas seeded to grass, including grassed waterways, grassed turn areas and grassed backslopes.

Parallel area—all row-cropped areas that terminate at field boundaries or grassed turn areas.

Nonparallel area—all row-cropped areas not included as parallel area.

RESULTS

Total field area and terraced area were analyzed to determine the average field size and the portion of each field terraced. The total field areas ranged from 7.6 to 20.0 ha per field with an average of 15.4 ha per field (Table 1). The terraced area ranged from 7.5 to 17.8 ha per field for an average of 13.1 ha per field. Eighty-five percent of the total field area was located above the bottom terrace, indicating nearly complete protection of the entire field area. The field areas were typical of fields in the Missouri Valley loessal hill areas.

The terraced area was divided into parallel and nonparallel areas. Parallel areas terminated on field borders or grassed turn areas and were easy to farm. Nonparallel row areas terminated within the field and were difficult to farm with large equipment by increasing turn time and soil compaction in the turn area. The constructed broadbase terraces had 24.2% nonparallel area compared to 17.4% nonparallel area for the terrace systems planned on a topographic map without allowing lateral soil movement. The grassed backslope terrace systems with tile outlets had 2.0% nonparallel area when lateral soil movement was used as an established practice.

The grassed area amounted to 9.7% of terraced area for the installed terrace systems, 9.9% of the terraced area for the planned broadbase terrace systems without lateral soil movement. The field constructed to grassed backslope terraces and grassed waterway had 4.2% of the terraced area in grassed waterways and 2.9% of the area in grassed backslopes. The grassed area accounted for 3.1% of the terraced area for the parallel grassed backslope terraces with tile outlets.

The length of terrace per ha of terraced area is another method of evaluating the coverage of the terraced system. The length of terrace per ha can generally be reduced by careful planning without reducing the effectiveness of the conservation coverage. The terrace length ranged from 125.3 m per ha for the constructed terrace systems to 113.1 m per ha for the terrace systems planned, with no lateral soil movement, on a topographic map. The terrace length was reduced to 74.4 m per ha for the grassed backslope terrace systems with tile outlets where lateral soil movement was allowed. All of the terrace systems adequately reduced soil losses to tolerable levels.

DISCUSSION

The terrace systems were planned originally to evaluate yields, soil and water losses from different

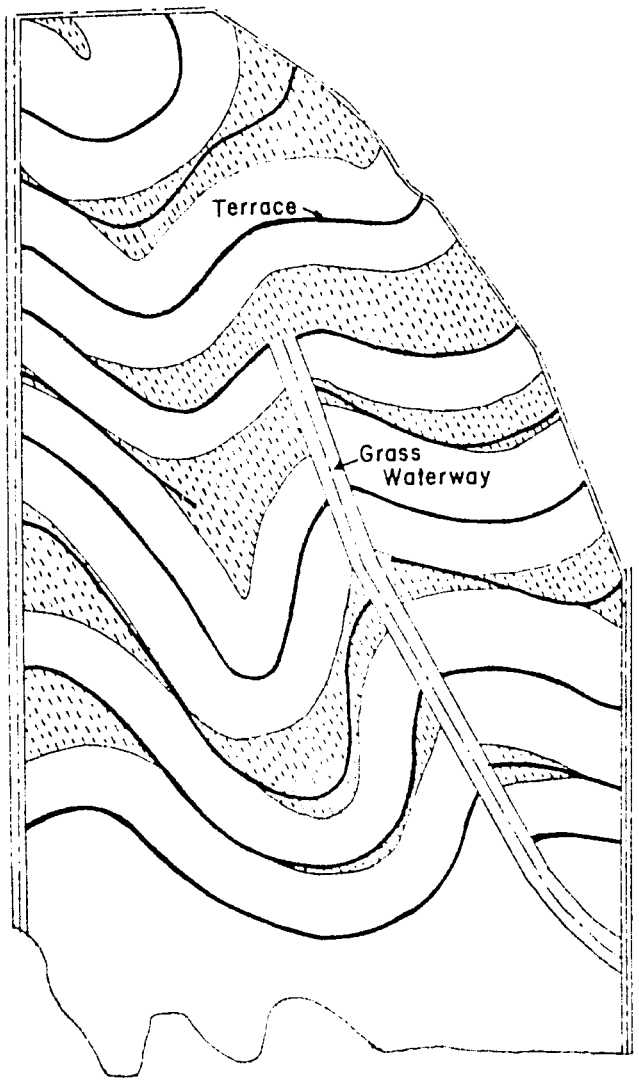

Figure 3. Field No. 2. Installed broadbase terrace replaced by paralleled grassed backslope terrace system—field area, 12.6 ha; terraced area, 10.0 ha; nonparallel area, 29.1%; terrace length, 263.5 m/ha.

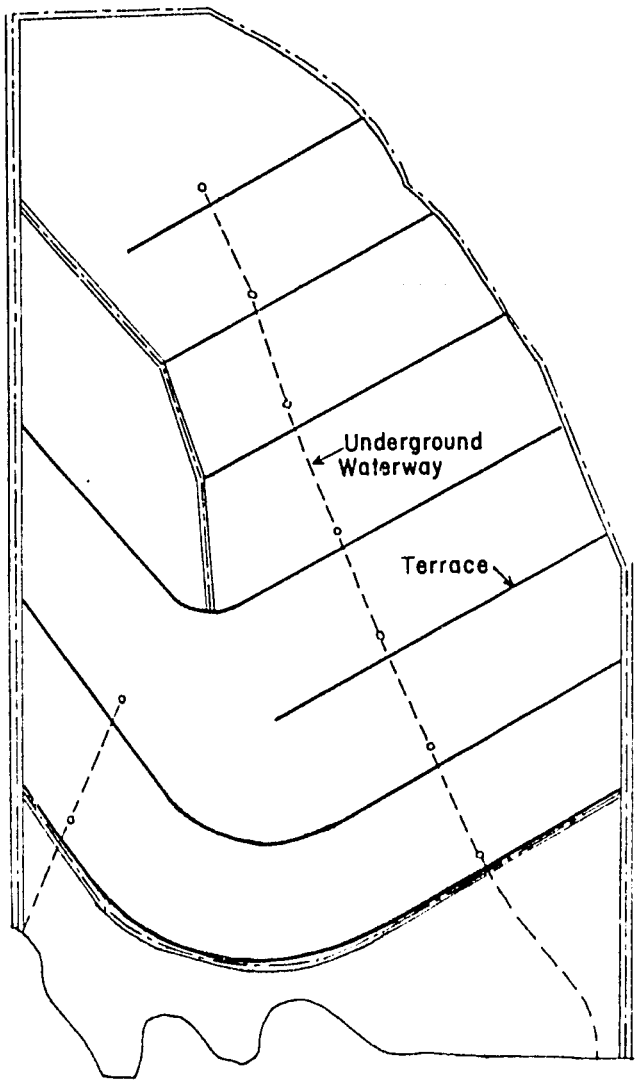

Figure 4. Field No. 2. Paralleled grassed backslope terrace system with tile outlets—field area, 12.6 ha; terraced area, 10.7 ha; nonparallel area, 0.5%; terrace length, 156.6 m/ha.

conservation systems. The parallel grassed backslope terraces with tile outlets were considered the optimum in conservation development but the parallel grassed backslope terraces with grassed waterway were installed for a comparison of the two systems. Grass waterways offer more obstacles to farming than underground waterways. Grass waterways do not store runoff water and thus allow a higher runoff rate and greater soil losses in the runoff water than the underground waterways which reduce the runoff rate to 2.5 cm in 24 hours.

Terraced area was used to analyze the different terrace systems because the construction costs per unit area are less variable and the terraced area can be used to project other terrace evaluation parameters (Wittmuss, 1973).

Lateral soil movement was not considered for the design of the terrace systems in 1949 because the cost of soil movement was considered too high. Parallel terraces were hard to justify with the 22-kilowatt tractors and two-row planting equipment used at that time. The change in the availability and cost of using soil moving equipment and the demand for parallel terrace systems have changed appreciably over the 22-year period.

The grassed backslope lengths were measured for two terraces of each system to determine if the terraces were installed as designed. The grassed

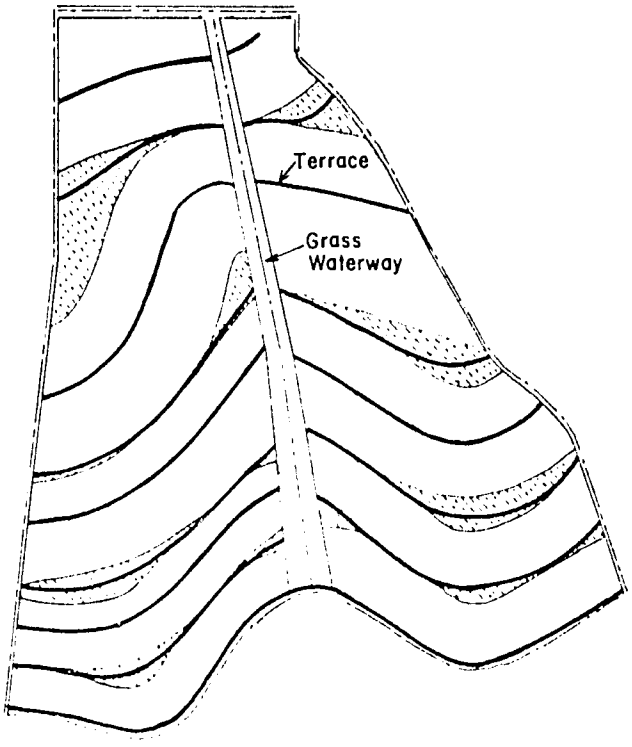

Figure 5. Field No. 3. Installed broadbase terrace system replaced by parallel grassed backslope terrace system—field area, 7.9 ha; terraced area, 7.7 ha; nonparallel area, 15.6%; terrace length, 319.2 m/ha.

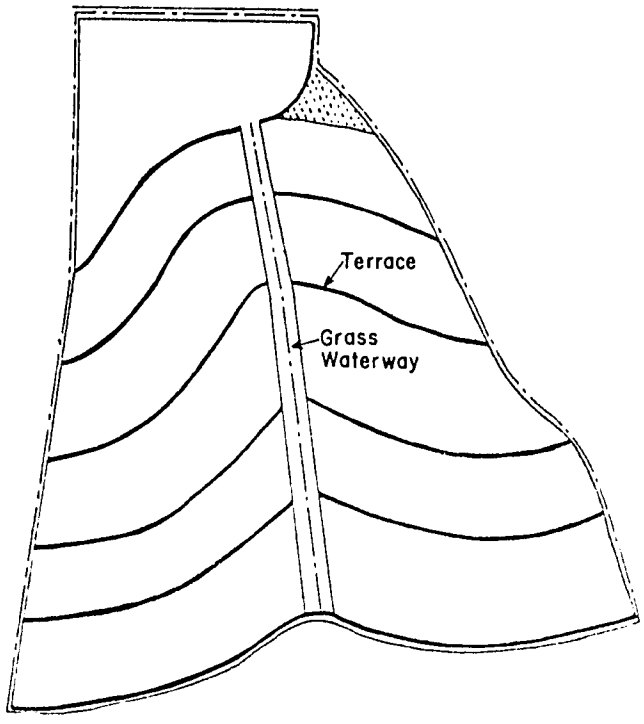

Figure 6. Field No. 3. Paralleled grassed backslope terrace system with grassed waterways—field area, 7.7 ha; terraced area, 7.6 ha; nonparallel area, 1.1%; terrace length, 237.9 m/ha.

backslopes actually occupied twice as much land as designed using a 2:1 backslope. Design shape for the terrace backslopes was used in this analysis since the optimum terrace design was considered. The wider terrace backslopes were a result of inadequate terrace construction, supervision, and checking. Grass backslope lengths should be closely supervised when they are installed to reduce the grassed area which has a low economic crop return.

The parallel grassed backslope terraces were installed on fields with land slopes ranging from 5 to 8%. Many visitors inquired about the advisability of using grassed backslopes when broadbase terraces could have been used with the resulting increase in farmable area and reduction in upkeep costs. Broadbase terraces greatly increase the soil moving requirement in the water storage sections. Broadbase terraces are recommended for the graded ridge sections on land slopes up to 8% and grassed backslope terraces in the level ridge cross section. On slopes 8% and greater, grassed backslope terraces are recommended for both the graded ridge and level ridge cross sections. Such a system would provide for maximum farmable field area, lowest construction cost for the terrace system, and reduce maintenance cost and problems.

The personnel time required to design the parallel terrace systems manually and the high cost of underground waterway installation with clay tile were obstacles in the acceptance of the grassed backslope terrace systems. A computer program (Forsythe, 1969) was used to design the terrace system installed in 1970. The parallel grassed backslope system design required 12 man hours to stake the terraces on 4.9 ha, submit for computer design, and mark stakes for construction. The parallel grassed backslope terrace system was designed in the same time required to design a nonparallel broadbase terrace system on the land. A farm tractor-operated tile trencher using plastic tubing and risers which reduced the construction cost 50% were used for the underground waterway system. The new innovations made the parallel grassed backslope terrace systems more acceptable to farm owners.

Prior to the use of the computer for terrace design, ridge type terraces were used for the entire terrace length. The computer designed ridgeless or channel terraces on the high terrace locations and grassed backslope terraces in the lower level ridge section of the terrace. Soil was moved laterally from the high terrace channels to the level ridge sections with a resulting reduction in total soil movement. The

computer-designed terrace systems need further evaluation and testing before accepting the method completely but the reduced personnel design time requirement and reduced soil movement are factors which tend to make the computer-designed terrace systems more readily acceptable.

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DISCUSSION

S. Vasuvat (Thailand). In Asia the acreage for farming is very small and every inch of land must be used. So, peasant farmers might not appreciate that broadbase example. I would like your idea of what should be done to convince the farmer. For example, could trees be planted on the ridge of the terrace instead of leaving it as grassland?

Wittmuss. Trees have such a prolific root system that they would dry out the soil for some distance. You could probably use some plants with less extensive root systems that would not extend out into the cropped area. It may even help if these were 3 or 4 feet tall. This would cut down wind velocities and improve your situation.

Vasuvat. The farmer feels very badly if, to make the channel and the ridge, he has to excavate a bit of soil up to the ridge zone. But that area of the land is very poor.

Wittmuss. You could use some crop of a permanent nature that would survive on such land.

C. Adamson (Australia). I'm surprised with the use of the grassed backslope on the terrace. We have deviated from, say non-cultivated area, in our system because of weed infestation, if we have an area within the paddock which we cannot cultivate. We now have gone to a broad-based terrace that is different from yours. We have a 6:1 slope on both the channel and the downslope and this way we can cultivate and plant both the uphill, the channel, and the whole of the bank and have no trouble with weed infestation. I was wondering if you would comment on this.

Wittmuss. I get reaction on both sides. Some people like to have a grass backslope even on flat slopes—don't ask me why. You can't hold your equipment on steep backslopes. That's the reason the farmers themselves just naturally go to this system. So, when you get on steep slopes you really don't take much land out of production and the rest of the land you have is very farmable. Weeds have not been a serious problem. We plant them to grass and the grass grows quite well; we can control them with herbicides.

E. J. Ravalo (Puerto Rico). You mentioned that your computerized design greatly reduced the design time for obtaining the optimal terrace design. Would you discuss the mechanics of the working of the computer problem?

Wittmuss. It's really very complex to discuss this in a short time. We determine the channel rod readings and then we will design the channel configuration we would like. We put these two things into the computer and the computer will then lower or raise that terrace channel until it gets a balance of cut and fill soil. It will also, in a storage terrace, work out the storage requirements of that terrace and will give us a computer print-out on that. It will give us back the original ground rod reading, the channel rod reading, the ridge rod reading for each station and it will give us a cut, the fill, and the cubic yards moved for that section of terrace between two stations; whether it's net cut or net fill; it will tell us what size orifice we need in our terrace outlet so that the water runs out, let's say at 1 inch in 24 hours, 2 inches in 24 hours. It's a very complex program and it will give us the amount of work, the amount of cubic yards per fill, cubic yards of cut, the cubic yards if it has to move any great distance with a scraper or a pan, it will give us the feet of terrace that does not require cutting and filling, and it will give us the length of terrace that requires filling. It gives us a very complete analysis of our terrace.

Ravalo. Do you specify in the program the coordinates of the waterway locations by station? Do you specify locations of the outlets?

Wittmuss. If you design the terrace channel, you would select the outlet therein because it would be the lowest location. If you didn't, we can put in a drain point. The drain point—and that's the station—of which we would have that terrace drained and then the computer will select the channel for us. This program started at SCS, they did a lot of initial work on it, and then we have been working on it, in Nebraska for the last two years and we now have a beginners' program that I have my students use in class. They can design terraces without much help from me.

Vasuvat. In this type of broad-based terrace you use a machine for construction but I think the machine has a slope limitation. If the slope is very steep, you cannot use a machine. So, that is the slope limitation.

Wittmus. The slope limitation on the front slope is 6:1. If we work the thing on a computer and it gets steeper than 6:1, then we use what we call double-base. We lengthen out the base. And usually we make the riser two widths because in time the terrace tends to build up and the width becomes narrower and then you can't get around that with a machine without going over the edge. If we make it two widths we can make a double pass.

Unidentified. What is the maximum slope that you can put a broadbased terrace on?

Wittmuss. On any slope, but I don't like to go over 15%.

Unidentified. What would be the maximum percentage of slope that you could put one on—15, 30?

Wittmuss. I think in our area, there's an economic limit.

Unidentified. He is asking for the maximum percentage slope since the slopes that he was showing were 50%. Would you put a broadbase terrace on that?

Wittmuss. I don't know. We haven't been faced with this problem and it wouldn't be economical for us, but where you have needs for food production, you can do a lot of things that we can't do.

Unidentified. For the small-size farm, land is very precious.

Wittmuss. But you're not so concerned about this parallelism and efficiency of production. You're concerned about maximum production. You'll make your own soil if you have to. We can't do that.

Unidentified. What kind of grass do you plant on the backslopes?

Wittmuss. We have tried many. I suppose we would prefer to see native grass plantings but generally we use bromegrass because it is better adapted to our climatic conditions; even if we plant native grass the bromegrass would probably take over.

Unidentified. Doesn't what we've seen here about the intercropping suggest very strongly that those grass backslopes and waterways could be used for tree crops?

Wittmuss. Well, on the waterways you couldn't—if you could drive through them it would be all right. You see, you have to drive through a grass waterway. Now on the backslope you don't have to. You could use it for some crops that wouldn't have such an extensive root system.

D. Plucknett (Hawaii, USA). They would have to determine which crops would relate to the row crops, such as dwarf apple trees.

Wittmuss. Well, they certainly could be and it would give you better protection. It stabilizes soil probably better than grass. Another thing, one of the problems with a lot of grass waterways with herbicides is that the herbicides take out the grass and then we have a real problem because we have no protection there.

75.
Traditional Slope Management: An Analytical Approach*

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Several characteristics of slopes distinguish them from other farming environments. Best known are debris transport forces as manifested in mass transfer and various surface water flows. These gravity-driven forces are dependent upon differences in elevation and are the same everywhere (Carson and Kirkby, 1972).

Most farming practices lower resistance to debris transport. Original clearing and subsequent cultivation reduce mitigating effects of vegetation on surface flows and soil erosion. Tillage loosens surface materials and weakens shear resistance to soil removal. Successful slope farming requires compensatory practices that decrease or interrupt overland flows or reduce gradients. Such practices, no less than farming itself, involve expenditures of energy.

This is the essential dilemma of traditional or non-industrial systems. Natural forces are the same in all comparable environments. But traditional farmers lack the concentrated power of fossil-fuel driven equipment and must seek solutions to slope management problems within the severely limited capacities of human and animal power units.[1]

One solution is to reduce scale, to divide tasks into manageable units that can be accomplished by individuals or small groups. Equipment sets limits to scale reduction: hand tools are most flexible, animal-drawn equipment is more space-demanding. Thus there is a conflict in traditional systems between relatively space-expensive animals and arduous human work. But in addition, there are no suitable animal-powered tools for many operations such as lifting and fine excavation. For these reasons a high proportion of traditional slope management is done with hand labor.

Massed labor offers another solution. If adequate labor supplies and appropriate socio-political organizations exist, there are few projects that cannot be accomplished entirely or substantially with human labor. But slope management does not exert the organizing influence of water management (Wittfogel, 1972) and even where labor is abundant, institutional requirements make this solution available to only a few societies.

With this brief introduction we shall now consider a few traditional approaches to slope management. Objectives are the same as in any system: to impede downslope movement of soil, conserve water, or create planting surfaces where other resources can be controlled. Specific techniques are presented as illustrations for a set of maxims or principles of traditional slope management. Examples are all from Middle America. Data on labor inputs permit comparison of relative costs of various slope treatments.

MAXIM 1: DO NO MORE THAN NECESSARY

In many instances only slight slope modification is adequate to achieve acceptable levels of control of surface runoff. In fact, the most extensive slope management systems in Middle America consist of sloping terraces on which original gradients are changed only slightly or not at all. They range from nothing more than rows of logs or rocks laid perpendicular to gradients to more elaborate earth or rock embankments (*bordos*), often reinforced with economic plants, and paralleled by drainage ditches (*zanjas*).

The drain embankment (zanja-bordo) system shown in Fig. 1 is typical. Trapezoidal drains are laid out along contours, then precisely cut with shovels, pickaxes, and spades. Excavated material is piled immediately upslope in geometrical bordos and planted to young *maguey* (*Agave* spp.). Terrace widths depend upon slope gradient, soil texture and depth, and intended use. Representative widths on moderate (1 to 10%) slopes might range from 10 to 30 m, to 3 m or less on steeper (up to 25%) slopes (West, 1968). Although sloping terraces are not customarily leveled, they develop modified gradients from natural and cultural processes. Thus deposition builds up behind embankments, and, consistently turning furrows downhill, transfers soil in that direction and reduces gradients.

Field observations corroborated by figures from Mexican government public works projects provide reasonably reliable data for estimating labor requirements. Workers are paid on the basis of *tareas* or *journales*, a fair or normal amount of work that can

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[1]An operational definition of traditional farming based upon power sources is better suited to a discussion of slope management than socio-economic distinctions embodied in such terms as peasant-, subsistence-, or small-farmer.

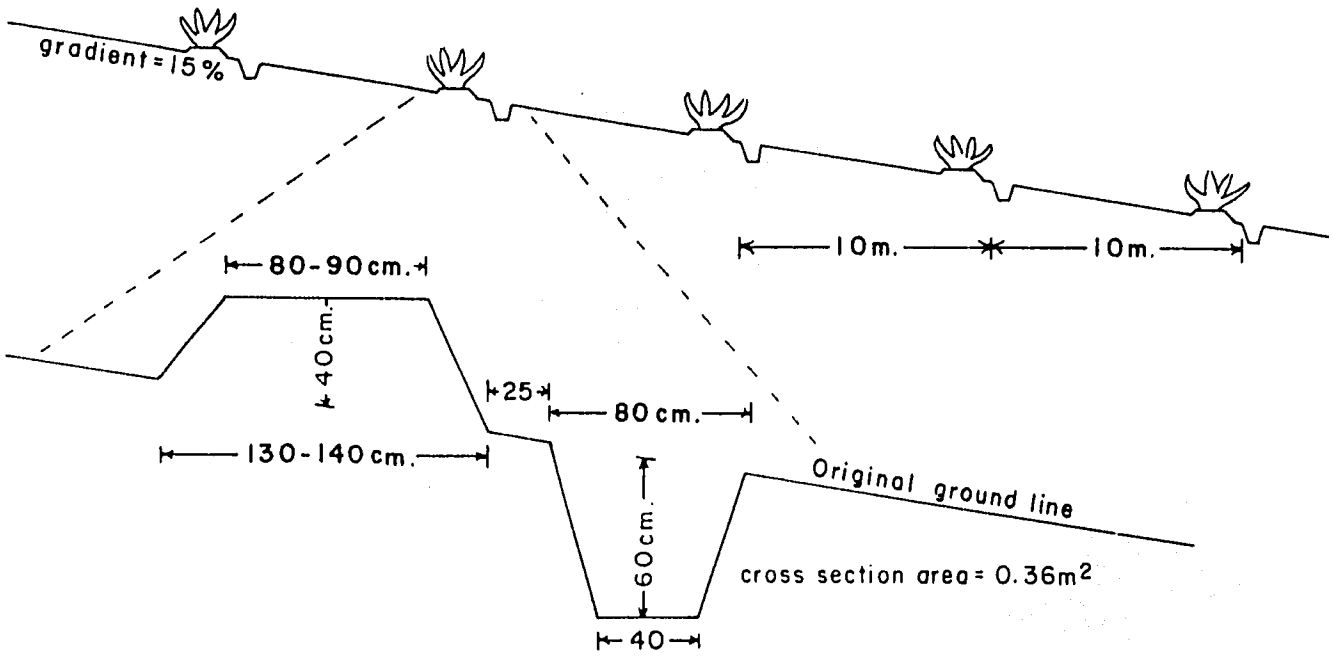

Figure 1. Sloping terrace (zanja-bordo).

be done in six hours. Table 1 presents representative work quotas for central Mexico. Within the indicated ranges, precise amounts are determined by specific conditions. For example, workers may be assigned 10 linear m of zanjas in heavy clays, but 15 m of clay layers account for only the bottom few centimeters of a drain in otherwise loamy soil.

TABLE 1. Daily tareas for *Zanjo-Bordo* construction (6-hour day)

Type of Material	Tareas in Linear Meters	Cubic Meters (Area = 0.36 m²)
Soft soil	20-25	7-9
Compacted clays	10-15	3½-5½
Tepetate	5-10	2-3½
Rocky	1-5	½-2

Although far from complete, the data permit some preliminary analyses of labor requirements. With representative average terrace width of 10 m and allowing an additional 10% length for contour sinuosity, a ha of hillside would have a total of 1 100 linear m, involving excavating and transferring a total volume of (0.36 m^2 × 1 100 =) 396 m^3 of material. Total labor investment would vary from 44 man-days in soft or sandy soils to more than 100 days in hard *tepetate*, a consolidated tuffacious material. Since this type of work usually is not undertaken on rocky slopes or in pure tepetate, most sloping terrace construction would fall into a range of perhaps 50 to 70 man-days per ha.

It would be possible to calculate monetary labor costs simply by multiplying prevailing wage rates by number of man-days. But most traditional slope management is undertaken by individual farmers and their families, perhaps with a few friends on an exchange labor basis, and only occasionally with hired hands. The cost is more realistically represented by the 50 or 70 days it takes to treat a ha of hill land than by monetary wage equivalents. As one Otomí Indian puts it, "bordos don't cost money; they cost work" (Haring, 1974).

There are many situations where sloping terraces achieve acceptable levels of water conservation and debris transport control. Compared to other management treatments, labor costs are extremely low. Entire farms can be terraced for relatively few man-days of labor and easily maintained by individual farmers.[2]

MAXIM 2: MINIMIZE SCALE

The ultimate in traditional slope management is reached in flat or bench terraces which completely transform slopes into level fields.[3] But bench terraces involve significant transfers of material, one of the

[2]The maxim of minimum expenditure of effort does not preclude careful work or even labor for social rather than economic rewards.

[3]Although bench terraces are not unique to traditional farming, they generally are not recommended for industrialized systems (Schwab *et al.*, 1971); USDA, 1954.

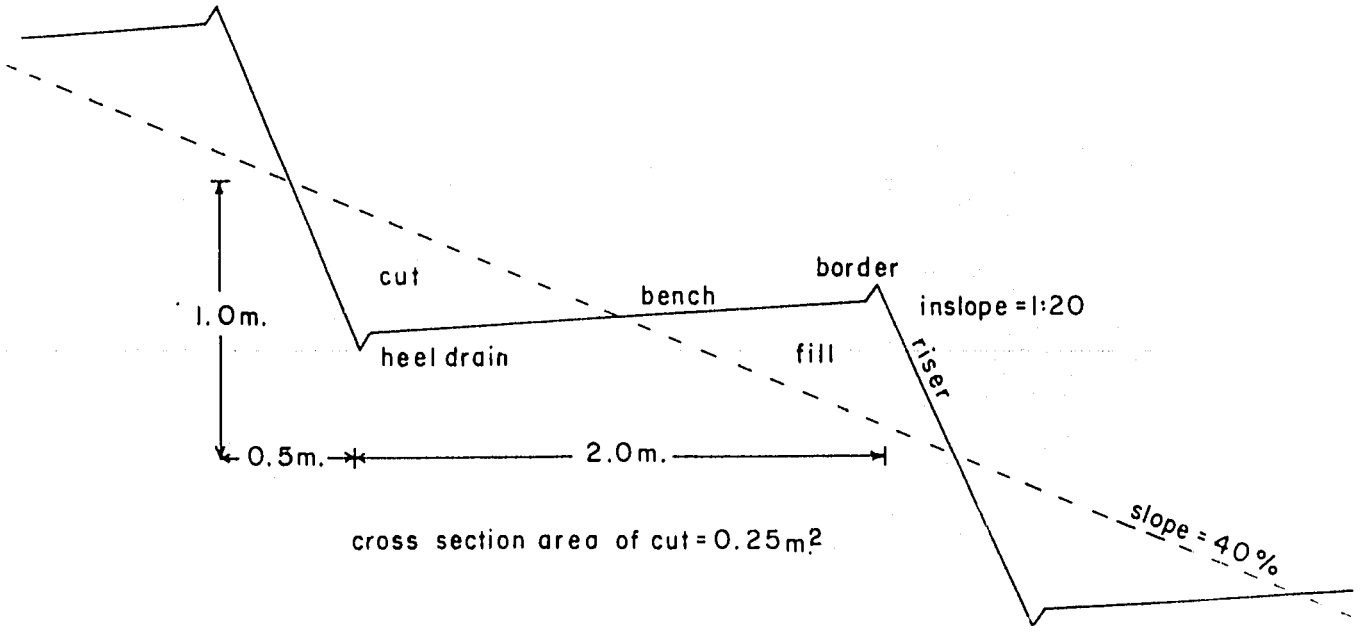

Figure 2. Flat or bench terrace.

most difficult tasks faced in low-energy societies. Since on a given slope, volumes excavated increase geometrically with terrace widths, traditional farmers tend to keep benches as narrow as possible.

The cross-sectional area of a typical bench terrace shown in Fig. 2 is 0.25 m^2. At the indicated spacing and gradient about 37 tiers of terraces are needed to cover 100 m of slope. Allowing an additional 10% for contour sinuosity, each hillside ha would require 4070 lineal m of terrace. Total volume to be cut and filled is slightly more than 1000 m^3. The result would be more than 8000 m^2 of flat fields on what had been sloping hillside.

Farmer estimates for excavating, filling, and forming micro features (e.g., heel drains, borders) on terraces of these dimensions cluster in the range of 20 to 25 lineal m (5.0 to 6.25 m^3) per 6-hour-day in soft soils. In heavier clays, construction rates drop to 10 to 15 m (2.5 to 3.75 m^3) and in rocky soils or tepetate to 5 to 10 (1.25 to 2.5 m^3) per man-day. Equivalent volumes are lower than those developed for sloping terraces (Table 1) since greater care is necessary in shaping and compacting flat terrace fills and forming micro features.

At these construction rates, total labor investment could run to more than a man-year per ha, probably more than most traditional farmers can afford. One solution is to make these already narrow terraces even smaller. By reducing bed widths and riser heights by half, twice as many lineal meters of terrace are needed to develop the 8000 m^2 of flat planting surface. Total volume excavated, however, is only about 500 m^3 per ha. If total labor investment is not halved, at least it would be reduced significantly.

MAXIM 3: WORK WITH GRAVITY

This approach was first suggested in the discussion of sloping terraces where some gradient modification was achieved by erosion and deposition. Silt-trap terraces and streamway check dams throughout Middle America use the same principle to create level fields and add fertile deposits. Farmers in western Guatemala go a step further and use gravity to help till much larger areas than they ordinarily could.

Basically, Guatemalan unirrigated hoe terraces (*tablones*) are bench terraces. Flat or slightly convex beds 0.5 to 1.5 m wide rise in tiers 0.2 to 0.8 m high. Riser backslopes vary with gradient, from near vertical on gentle slopes to ½:1 on steep hill-sides. Wheat is the most common *temporal* (rainfall) crop but maize and broad beans (*Vicia faba*) also are popular.

Narrow tablones are formed and cultivated solely with broad hoes (*azadones*), the universal farming tool of this region. Tablón beds are not tilled prior to planting. Instead risers are shaved off and the dislodged material is pushed and pulled across benches burying old surfaces under a layer of loosened soil (Fig. 3). For wheat, farmers strive for a layer about 5 cm deep. As soon as a few tiers of tablón have been prepared, seed is sown and covered (*tapado*) with an additional 2 cm of soil shaved off the riser. In the example illustrated in Fig. 3 about 12 ½ cm would be shaved off to produce the total of 7 cm of soil spread over tablón surfaces.

This method of plot preparation has several advantages. Erosion potentials are greatly reduced

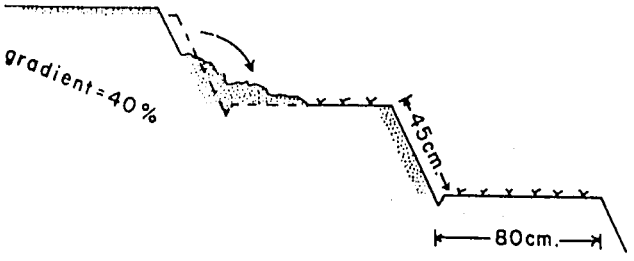

Figure 3. Tablon tillage.

since old compacted terrace surfaces, complete with dry or burned stubble and residue (*basura*, literally garbage), and root systems from previous crops remain intact. Only a thin layer of loosened soil is exposed to splash and sheet erosion. Organic materials and ash are interred at root levels of the new crop. Layers of loosened soil may suppress weed growth. Since soil from the whole riser is incorporated into planting beds each year, all soils are rotated on a long-term basis. The terraces shown in Fig. 3, for example, would be completely rotated every 6 or 7 cycles.

But most important, the system requires much less effort than would digging up terrace beds. An experienced azadón wielder can prepare 100 lineal m of terrace an hour. With steady work, farmers expect to till, sow, and cover a *cuerda* (ca. 440 m^2) of tablón in a 6-hour working day. In the example given this would involve cutting and transferring 25 to 30 m^3 of soil per day, considerably more than is possible with ordinary shovel excavation.

MAXIM 4: MANAGEMENT IS A PROCESS, NOT A PROJECT

Scheduling project phases and completion dates is a luxury of industrialized systems. Lacking control over large power units (and many other variables) traditional farmers must think small, of incremental changes over long periods of time. Extensive terracing or erosion control may be undertaken with little thought as to pace of work or final completion. Thus many traditional slope management activities resemble ongoing processes more than fixed projects, especially where total labor costs are high.

Terrace walls, for example, are extraordinarily labor-expensive to build. Direct data are not available. But from studies of rock check dams (Herold, 1965), building wall construction rates (Erasmus, 1965), Mexican public works quotas, and my own field observations I calculate that farmers can lay dry stone walls at somewhere between 1 and 2 m^3 per day if suitable materials are at hand. But materials transfers also are expensive. From Table 2 it is apparent that if wall materials are only 100 m distant, construction times could double. Mortaring requires additional time. With insufficient data I can only guess it might reduce construction rates by 50 to 75%. (Fig. 4).

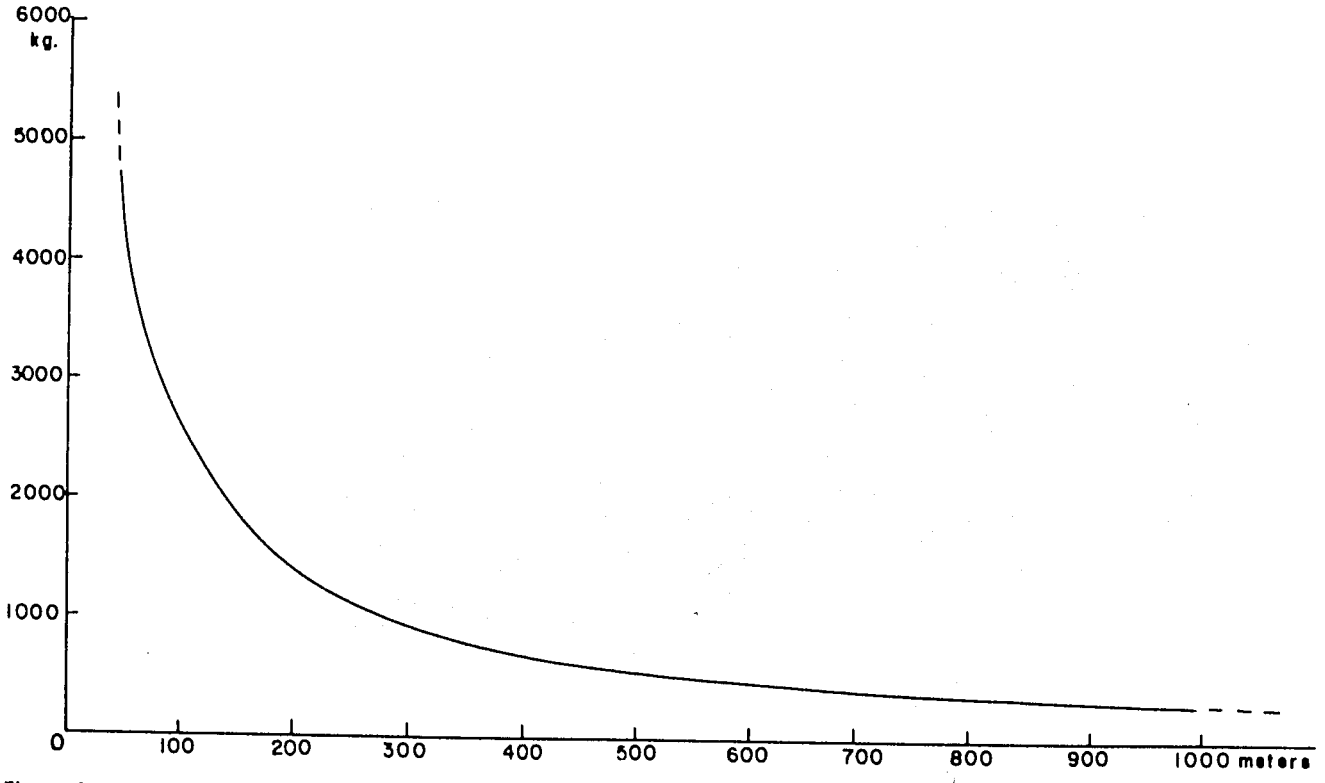

Figure 4. Distance-load relationships for human carriers.

TABLE 2. Materials transfer rates by human carriers (6-hour day)[a]

Trip Distance (one way, m)	Material	Total Trips	Total Distance (round trip, km)	Avg. Wt. Carried per trip (kg)	Total Wt. Carried (kg)	Total Volume Carried[b] (m^3)
50	earth	234	23.4	20.2	4716	3.63
100	earth	134	26.8	19.9	2672	2.06
250	rock	39	19.5	27.9	1088	0.76
500	rock	23	23.0	25.0	575	0.40
750	rock	17	25.5	34.5	586	0.41
1000	rock	13	26.0	22.7	295	0.20

[a]After Eramus, 1965. Rock data adjusted from 5- to 6-hour day.
[b]Volumes calculated: 1 m^3 = 1300 kg earth or 1440 kg rock.

If an overall range of 0.25 to 2.0 m^3 per day is within reason, then 100 m of modest, meter-high wall 20 cm wide at the top and 80 cm at the bottom (area = 0.5 m^2) would take from 25 to 200 man-days to build. To erect walls over a hillside would involve very large investments of time and effort indeed. If terraces are leveled, additional labor is required for arduous materials transfers. I suggest that most traditional walled terrace systems were built slowly, in small increments, over tens or even hundreds of years.

MAXIMS ARE NOT MUTUALLY EXCLUSIVE

A final example will demonstrate how slope control techniques often embody several principles of traditional management. In Middle America various types of small, discrete, or partial terraces are used when soil or crops are not continuous. Circular pit terraces (*cepas*) around individual trees in hillside orchards are common and will serve to illustrate.

Cepas are constructed by cutting and filling just as are ordinary flat or bench terraces (Fig. 5). They perform all customary terrace functions such as controlling erosion, conserving moisture, and facilitating cultivation. In addition, this form of terracing has some unique advantages. Unworked portions of slopes remain at original gradients and under vegetation, thus reducing erosion hazards. Irrigation water delivered through small canals or tubes is confined to immediate tree areas and water use is minimized (Obregón Formosa, 1973).

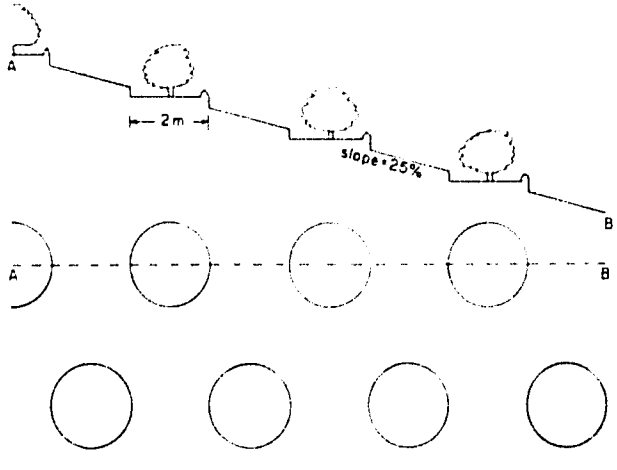

Figure 5. Pit terraces (cepas).

But most important, since reorganization of surface geometry is kept low, little labor is necessary. For example, it would require excavating less than 0.2 m^3 to construct one of the cepas shown in Fig. 5. At indicated spacings, each ha would have about 722 cepas. Assuming labor rates are similar to those for bench terraces, it would take only 23 to 58 man-days to construct pit terraces in a ha of hillside orchard.

Scale is small. In new orchards circular areas only slightly larger than seedling crowns are leveled. As trees grow, terraces are enlarged. Such phased expansion suggests something of the process rather than the project approach. Materials transfer from cut to fill are downslope, assisted by gravity. Once formed, cepas trap surface wash and debris to enrich immediate tree areas. Thus the several rules of traditional slope control find expression in a single management form.

CONCLUSIONS

Despite power limitations, traditional farmers are capable of impressive results in slope management. For example, over the years thousands of ha of mountainous Middle America have been molded into forms which, if properly maintained, effectively control erosion, conserve moisture, and create productive fields in areas otherwise marginal or unsuitable for farming. When conditions are right, hand labor can achieve results equal or even superior to powered equipment.

The two systems are not incompatible. For some tasks, such as long-distance transfers and compaction, powered equipment is best. For others, such

as fine excavation on narrow bench terraces, hand labor may be superior. Traditional methods of slope management should be viewed as an alternative technology, to be evaluated in relation to environmental and socio-economic conditions, and to the tasks at hand.

But a cautionary note is in order. Hill farming and management partially destabilize slopes. With original vegetation removed and gradients modified, degradational forces are held in check only as long as control forms, such as terraces, remain intact. Constant surveillance and maintenance are necessary to prevent failures that can result in rapid deterioration of entire slope systems. But maintenance, like original construction, requires effort. Since traditional systems depend upon humans both for management and for power they are particularly sensitive to social, political, or demographic disruptions that might reduce labor available for maintenance. Some of the worst erosion in Middle America has occurred in regions once intensively managed but subsequently neglected or abandoned (Spores, 1969; West, 1968).

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DISCUSSION

Unidentified. Are there terraces laid off just by eye or do they try to do it exactly with some instrument?

Wilken. Some of these farmers now are getting a simple bubble level to help their work. Before they judged by eye, and on occasion on the bench terraces when they had a little heel drain on it they'd bring a little water up and it will flow along and they get an idea of the gradient from the running water. That's the traditional way they handle this.

H. Wittmuss, (Nebraska, USA). They have these systems quite well developed. If for some reason for one year they would fail to keep it up—say they would not plow the row seriously—what happens in those cases? Is it stable enough in these situations you're showing us that this will be continued year after year with no break down in usage?

Wilken. I was wondering if I could conjure up the idea here that we're talking about land and we're talking about population densities which at one time provided the incentive for maximum usage, but on the other hand it also is supplying whole energy. They have the energy source that drives this system. Yes, you can get a family which for some reason is in trouble, somebody gets sick or something, and the field goes fallow and they can get into trouble very quickly.

Unidentified. Is this a serious problem?

Wilken. No. Interestingly enough I looked at hundreds of acres there and I only saw about two examples of this sort of erosion. The slides I took of the eroded fields were associated with unusual circumstances where road engineers had simply let a gutter drain off and dumped it into a man's field and then he was faced with a situation that he couldn't handle. But by and large they are quite stable. Some of these terrace systems may be hundreds of years old.

E. Oyer, (New York, USA). It seems then that the rainfall comes in a relatively well-distributed pattern with no torrential downfalls. If that is correct, what is the management year after year? I didn't see that there was a lot of new organic material being put in there and I presume that for the sake of economy they don't add the fertilizers. Is there a rotation of the terraces or how is the fertility reestablished each year as the terraces are reworked?

Wilken. The very large bench terraces that were being hand-watered are extraordinarily managed—they get everything—chemical fertilizer, manure, and extensive dressings of leaf mold on occasion; they are renewed constantly. They are under intense vegetative cultivation and the degree of care and production rivals the sorts of things we normally associate with oriental horticulture, so you have

these very carefully managed plots. In the very extensive handmade drain terraces they get the stubble from each year and this remains at the surface, another erosion prevention system by the way. In some cases, they get a little dressing, usually not much. I'm not sure about this but I suspect there's a very long-term fallow system with forests. There seem to be woodlots in that area and I suspect that those are rotated around so that on a 20-year cycle, those terraces may go into woodlands and then back out again as farms at some other period after that. I have not been able to look at that system long enough to know if that is true but I'm suspicious of these woodlots that show up right in the middle of wheat fields. Some of these woodlots are growing on old terraces. The only thing that I can conclude is that the trees are allowed to grow in a long-term rotation.

H. Wang (Republic of China). You mentioned a circle terrace. According to our experiments, if it just approaches a circle, which we call an individual basin, then compared with untreated soil the soil loss is almost the same if you combine hill side litchi and some cover crop.

Wilken. Yes, in those pit terraces or circular terraces the rest of the slope remains either in natural vegetation or is seeded in something else. I guess I'm not following from that argument. The terrace of course is exposed. That's bare soil which is cultivated, fertilizers are added to it, and so on. It also acts as something of a collection basin.

Unidentified. Do they use human wastes?

Wilken. Not systematically, but in these villages there's no sewage system or even outhouses and the fields are used as toilets. So, there is an incidental fertilizing going on.

Unidentified. Did they use such wastes in pre-Columbian times?

Wilken. Yes, in some areas. I know specifically only of one area of Central Mexico where human excrement from a large metropolitan area was systematically collected and taken out into the fields.

Unidentified. Was that Aztec?

Wilken. Yes, it came from the Aztec capital and it was carried by canoes down to the famous Chalco district and spread.

E. J. Ravalo (Puerto Rico). Those bench terraces appear to me to be very labor intensive. How many acres can a man maintain?

Wilken. Those bench terraces—the type we saw there—let me take just a horseback guess on this—there's the process of shaving off the face to get a planting bed, then the seed is sown, then they shave off a little more to cover the seed. It's a two-cycle operation and to completely till and plant they figure one cuerda per man per day—that's about 400 sq m per man per day for these bench terraces. Now the actual terrace formation will take longer. But the terraces themselves last for years—they're not dug up each year, they're simply renewed essentially. And I'm talking about 6-hour days as the normal workday.

75A.
Use of Aerial Techniques for Pasture Improvement in the Hill Lands of Iran

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Iran has 18 million ha of hill land with a relatively favorable climate for pasture growth (precipitation more than 400 mm per year) (Niknam, 1970). The hills have precipitous slopes with thin rocky soil (Shaidaee, 1974). Overgrazing, burning of all combustible species (Pabot, 1967) and plowing for crop production (Shaidaee, 1974) have destroyed trees and pasture, caused catastrophic erosion and extended the desert.

Pabot (1967) suggested that the hill land could be improved by prohibiting grazing and broadcasting forage seed. However, he warned that sowing without land preparation could only lead to failure, except in certain humid parts of Iran. Despite this, it was imperative that the use of aerial techniques for pasture improvement be investigated. Such techniques might halt the destruction of the hill land pastures.

In 1975, in response to an order from His Imperial Majesty, the Shahanshah Aryamehr, an investigation into the use of aerial techniques for pasture improvement of the hill lands of Iran was begun (Campbell, 1976). Seed and fertilizer were distributed on unplowed land typical of the more humid xerophilous forest zone of Iran.

METHODS

Sites

Four sites were selected in Kurdistan on the Zagros Mountains near Sanandaj (western Iran). Latitude was 35° N and longitude 47° E. Sites 1 and 2 were 34 km southeast of Sanandaj and sites 3 and 4 were 30 km west. Site 1 was a hill with three ridges and four dissecting valleys. Site 2 was an unplowed hill (42% slope) and an adjoining flat (5% slope), part of which had been plowed and cropped in 1974 and another part plowed and cropped in 1975. Site 3 was on a steep hill with an amphitheatre shape (replication 1) and the adjoining ridge (replication 2). Site 4 was on both sides of a ridge running ENE; one side faced NNW and had many animal paths, the other side was more heavily eroded with no animal paths (Table 1).

Climate

The area has a continental climate with hot, dry summers; warm, dry autumns; cold, moist (snow) winters; and mild, moist springs (Table 2). Precipitation before the experiments were sown (summer and autumn, 1975) was low, but was above average during the establishment of the sown species (winter and spring, 1976).

Soils

The soils, classed as lithosols and derived mainly from limestone, were very loose and soft, stony, shallow over bedrock, without profile development, alkaline (pH 7.1 to 7.7), low in organic matter, high in available phosphorus (16-25 ppm—Olsen test) and moderate to high in total nitrogen (0.12 to 0.24%).

Treatments

The treatments imposed on sites 1 and 3 were:

1. Double seeding—half the seed sown in early November, 1975, and half in early March, 1976.
2. Fertilizer—100 kg/ha of both triple superphosphate and sulfate of ammonia were applied in early November, 1975.
3. Double seeding + fertilizer—fertilizer and half the seed applied in early November, 1975, and the remaining seed in early March, 1976.
4. Single seeding + fertilizer—fertilizer applied in early November, 1975, and all seed sown in early March, 1976.
5. Control—no treatment.

Treatment 3 was applied to sites 2 and 4.

Seed and Fertilizers

All seed was treated with chlordane to reduce losses due to seed-harvesting ants (Campbell, 1966) which were observed on the sites. Only the legume seed sown in November was inoculated with *Rhizobium* spp. The species sown, seeding rates and percentage viable seed are shown in Table 3. Seed and fertilizers were dropped by helicopter from 30 m at 60 km/hr, and the swath was marked at 25 m widths. Because of the rugged topography, some seed was dropped on ridges from 30 m and some into the adjacent valleys from 100 m or more. Seed sown in November, 1975, fell on dry soil. Little rain had been received since April, 1975 (Table 2). Seed sown in March, 1976, fell on 0 to 10 cm of snow.

Triple superphosphate and sulphate of ammonia were applied at 100 kg/ha in early November, 1975.

Management

Sites 1 and 2 were grazed for two days after sowing in November to try and incorporate seed into the soil by treading. Sites 3 and 4 were not grazed after sowing. The sites were fenced and were not to be grazed until the sown species were considered to be resistant to grazing damage.

TABLE 1. Sites chosen

	Site 1	Site 2	Site 3	Site 4
Area (ha)	68	15	35	32
Plot size (ha)	6.8	2.5 and 8	Rep. 1 = 5ha Rep. 2 = 2ha	NNW = 17ha SSE = 15ha
General aspect	ESE	WNW	NNW	NNW and SSE
Slope (%)	28-51	5-42	45-65	37-67
Altitude (m)	1 600-1 900	1 610-1 670	1 510-1 750	1 480-1 630
Animal paths	few	many	many	NNW = many SSE = nil
Proportion of bare ground in late summer, 1975 (%)	80-90	40-90	60-80	NNW = 50 SSE = 99

TABLE 2. Monthly climatic data for Sanandaj (altitude 1 540 m)

Month	Precipitation			Screen temperature			
	Average[a]	1975	1976	Average[b]		1976	
				Max.	Min.	Max.	Min.
	mm			°C			
January	73.0		40.0	5.3	− 5.0	10.7	−2.6
February	57.8		63.6	7.7	− 3.4	7.3	−5.7
March	75.6	20.0	82.2	13.5	1.4	10.2	1.7
April	86.8	121.7	103.3	17.4	4.9	18.6	4.3
May	41.7	1.0	53.0	24.5	9.6	23.9	7.2
June	1.1	0		31.6	13.8		
July	0.7	0		35.7	18.7		
August	1.3	0		34.8	17.6		
September	0.9	13.7		30.9	12.4		
October	20.7	0		23.5	7.0		
November	47.0	42.4		15.1	1.8		
December	47.9	56.0		8.7	− 2.5		
Total	454.5						

[a]1960 to 1974 inclusive.
[b]1960 to 1971 inclusive.

TABLE 3. Seed mixtures sown on the plots and germination capacity of the seed

Species	Sowing rate Nov., 1975	March, 1976	Viable seed	Total amt. of viable seed sown
	kg/ha		%	kg/ha
Agropyron desertorum	1.0	1.0	72	1.4
A. cristatum	1.0	0.87	54	1.1
Bromus inermis	1.0	0.87	63	1.2
B. tomentellus	1.7	1.26	45	1.2
Dactylis glomerata[a]	0.5	1.1	53	0.8
Medicago sativa (Ranger)	0.8	1.8	89	2.3
M. sativa (Hamadan)	0.8	1.4	77	1.7
Onobrychis viciifolia	1.5	2.2	63	2.3
Poterium sanguisorba	—	2.1	—	2.3[b]
Total	8.3	12.6		14.3

[a]Cultivar, Currie, from Mediterranean introduction to Australia.
[b]Total amount sown—viable seed not ascertained.

Measurement

Establishment of sown species and botanical composition of the pasture were measured in June, 1976, by counting the number of plants present in 0.5 m^2 quadrats (2 to 5 quadrats/ha) and by measuring point quadrats distributed along one or two transects through each plot (Campbell, 1974).

RESULTS AND DISCUSSION

Establishment

Good establishment of sown species was achieved at each site (Table 4). Significant differences between sown treatments (1, 3 and 4) at site 3 were not clearly defined because the sensitivity of the experiment was limited by having only two replications. No statistical analysis could be carried out on the results at site 1, because light breezes spread seed down the hillside into treatments (2 and 5) that it was not intended to sow.

Percentage establishment of the sown species at site 3 (Table 5) compared well with results of experiments done in Australia (Campbell, 1974).

Factors Affecting Establishment

Location. Establishment appeared higher on sites 3 and 4 than on sites 1 and 2. Whether this was due to higher precipitation on sites 3 and 4 than on sites 1 and 2 could not be ascertained as there were no reliable climatic data for each area. It does suggest that results of aerial sowing will vary in the different rainfall zones of Iran.

Aspect. Establishment on the southerly and northerly aspects of site 4 was comparable indicating that, providing precipitation was adequate, aspect had little effect on establishment. However, aspect could affect persistence—greater persistence being probable on northerly aspects.

Slope. Establishment did not appear to be affected by slope, possibly because of the gentle precipitation in winter and autumn, 1976. No doubt heavy rainfall

TABLE 4. Establishment in June, 1976 (Mean number of plants per 10 sq m, adjusted to the nearest whole number)

Site treatment	*Agropyron*	*Bromus*	*Dactylis*	*Medicago*	*Onobrychis*	*Poterium*
1. 1 Double seeding	5	21	16	59	27	17
2 Fertilizer	3	4	4	5	1	5
3 Double seeding + fertilizer	18	18	29	46	17	16
4 Single seeding + fertilizer	14	9	17	20	8	6
5 Control	4	5	8	15	6	2
2. Unplowed hill	3	12	15	41	35	24
Old cultivation	5	5	5	31	17	5
New cultivation	2	24	24	66	20	10
	†	†	†	†	†	†
3. 1 Double seeding	49ab	58a	101a	149ab	21b	66a
2 Fertilizer	7c	9b	14bc	7bc	3c	2b
3 Double seeding + fertilizer	75a	87a	194a	373a	33a	73a
4 Single seeding + fertilizer	26b	56a	75ab	92abc	25b	61a
5 Control	6c	5b	8c	1c	1c	12b
4. SSE face	62	112	150	172	35	35
NNW face	34	85	185	217	19	38

†Within each column for site 3, values followed by the same letter do not differ ($P > 0.05$). Analyses were based on square root transformation of the numbers.

TABLE 5. Percentage establishment of viable seed—site 3

Treatments	*Agropyron*	*Bromus*	*Dactylis*	*Medicago*	*Onobrychis*	*Poterium*
				Percent		
1 Double seeding	3.7b *	9.8a *	10.6a *	8.5a *	22.9a *	31.4a *
2 Fertilizer	0.5c	1.5b	1.5b	0.4b	3.3b	1.2b
3 Double seeding + fertilizer	5.6a	14.5a	20.1a	21.2a	36.4a	35.0a
4 Single seeding + fertilizer	4.1b	20.0a	10.7a	7.7a	45.1a	29.3a
5 Control	0.5c	0.8b	0.9b	0.1b	1.1b	5.7b

* Within each column, values followed by the same letter do not differ ($P > 0.05$). Analyses were based on the angular transformation of the percentage establishment.

would reduce establishment by removing loose soil and seedlings, particularly on the steeper slopes.

Microclimate and competition. It was observed that establishment was assisted by bare soil, animal paths, bare waterways and rock screes, but depressed by competing plants. No data were collected on these observations.

Good establishment occurred on bare, small-stone screes. If the sown species can persist, this finding is important because much rangeland in Iran has scree microtopography.

Competition, especially from *Poa bulbosa*, reduced establishment. Where the percentage ground cover of resident species in early summer—the season of maximum ground cover—was over 50%, establishment appeared to be reduced. Herbicides could be used to reduce competition, but this would be costly.

Very loose soil appeared to reduce establishment. However, establishment was good on soil surfaces only slightly more compacted. These soils appeared susceptible to frost heaving which could reduce establishment. However, the number of frosts in the first 5 months of 1976 (98) was greater than normal (64); 50 seedlings withstood substantial frost effect.

Seed sown into old or new cultivation sites (Table 4) established only moderately well, which we attribute to very loose soil on the former and strong competition from wheat on the latter.

Time of Sowing. Establishment was achieved from both the November and March sowings indicating that, in the 1975–76 season, sowing any time between November and March would have proved successful.

Season. The 1976 spring (Table 2) favored establishment of aerially sown seed. However, as precipitation in winter and spring in Iran is relatively reliable, there is a good chance that establishment can be achieved regularly.

Pests. As seed-harvesting ants were active on all sites in November, 1975, it was necessary to treat seed with an insecticide to reduce losses. Rodents and birds took aerially sown seed in USA (Nelson *et al.*, 1970), but there was no evidence that animals took seed in Iran.

Nodulation. Most legume seedlings had nodules despite the November, 1975, sowing being broadcast into dry soil. These nodules appeared to result from native rhizobia, which is not surprising as the soils were alkaline and six species of resident legumes were present.

Growth. Most seedlings present in June, 1976 had from 2 to 6 leaves with some having 20 leaves. Seedlings were generally larger where the soil was bare, deep or fertile, where fertilizers were applied or where water was well supplied.

Species. The results showed that grasses, legumes and herbs can establish in Iran from aerial sowing. The species sown were those with seed available. Others which could be suitable, if seed were available, include: *Secale monantum*, *Hordeum bulbosum*, *H. fragile*, *Stipa barbata*, *Agropyron tauri*, Iranian cultivars of *D. glomerata*, *Festuca ovina*, *Astragalus siliquosis*, *A. cicer*, *Vicia villosa* and selected Iranian annuals.

Trampling after sowing. Establishment on sites 3 and 4, which were not trampled, was extremely good, indicating that seeds can enter the loose soil of Iran's hill lands without trampling.

Persistence. The ability of the young plants to survive the next few years will determine the success of this project. In range seeding in the USA, heavy losses occurred after establishment (Plummer and Fenley, 1950; Hull, 1974); however, sufficient plants remained to form a pasture.

Iranian pasture species are adapted to hot, dry summers. Thus, if the species sown in this project cannot persist, other species (Anon., 1970) and treatments should be tested to find a combination which is successful.

Fertilizer. Although fertilizers appeared to increase the establishment and vigor of the sown species, their full effect will not be evident until spring, 1977.

No fertilizer effect was observed on resident species from ground observations but, from the air, strips of darker green foliage were seen. On areas with sparse pastures, no fertilizer effect could be expected. Where resident species were dense, the effect was on herbaceous species, since few valuable grasses and legumes were present (Table 6).

Resident species. The resident species on the experiments in early summer, 1976, after seven months without grazing, consisted mainly of herbaceous species with some perennial grasses and few legumes and annual grasses (Table 6).

Aerial operations. The project showed that fertilizer and seed can be effectively distributed up to 1 900 m altitude in the rangelands of Iran. The main advantage of using a helicopter was that airstrips did not have to be prepared. Assessment by experienced rangeland pilots suggested fixed winged aircraft could also be used successfully.

The results indicate that pasture species can be established from aerial seeding in the hill lands of Iran. Final assessment of results can only be made after the persistence of the sown species has been ascertained. However, the initial results are sufficiently successful to indicate that further investigations on aerial seeding should be made in Iran.

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TABLE 6. Percentage ground cover of resident species in June, 1976

Site	Perennial[a] grass	Annual[b] grass	Legume[c]	Herb[d]	Bare	Sown species
		Percent				
1	4.0	1.3	2.2	21.6	70.8	0.1
2	21.0	2.5	2.5	30.0	43.0	1.0
3	9.4	2.7	1.6	26.7	58.4	1.2
4	7.5	7.0	1.0	24.5	57.5	2.5

[a] *Poa bulbosa, Bromus tomentellus, Hordeum bulbosum, H. fragile, Festuca ovina, Agropyron spp, D. glomerata.*

[b] *Bromus danthoniae, B. squarrosa, B. tectorum, Eremopoa persica, Henrardia persica, Heteranthelium piliferum.*

[c] *Astragalus stevenianus*, many other *Astragalus spp, Medicago radiata, M. rigidula, Trigonella arcuata, Vicia villosa.*

[d] *Achillea santholina, Aethionema grandiflora, Anachusa* sp, *Centaurea behen, C. virgata, Cousinia* spp, *Echinops* spp, *Euphorbia* spp, *Onosma* sp, *Salvia multicaulis, S. syriaca, Scabiosa plastina, Thymus rigidula, Turgenia latifolia, Zizphora rigida, Zogea lepturea.*

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75B.
Fertilization As a System of Improvement of Eroded Pastures*

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Of 6 420 000 ha of pastures in Yugoslavia, approximately 3.5 million are highly degraded by soil erosion. Grass yields from severely eroded pastures progressively decrease and actually are very low (4–6 MT dry matter/ha). Intensive eroding and bad management and overgrazing are the main causes of very low productivity of eroded pastures. Recent needs for more meat production obligate us to intensify grass production on the pastures for beef cattle feeding. For these reasons, we have started to investigate systems for improvement and rational exploitation of eroded pastures.

In this paper, our aim is to present only one aspect of pasture improvement—fertilization.

Field experiments have been carried out on three experimental fields, located under different bioclimatic conditions on very dissected topography, in order to have the results which can be easily applied to the improvement of eroded pastures in other conditions on large hilly areas.

CLIMATIC CHARACTERISTICS

Table 1 sets forth the data concerning the precipitation in the growing season—April–September. These data show that there is a rather large variation of monthly precipitation in one growth period. This is particularly important in fertilizer response of eroded pastures in hilly terrain.

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RESEARCH METHODS—SOILS

Soil samples in both disturbed and undisturbed conditions have been taken from the experimental fields for laboratory analyses. These were made according to the following methods: (1) texture in percent—the preparation was done according to the international B method, and the separation of fractions according to the pipette method; (2) the hygroscopic soil water by the method of drying the soil samples at the temperature of 105 C; (3) the capacity for air in cylinders of 100 cm^3 according to Kopecky method, field capacity (retention of soil water) at 0.33 atmos. on the pressure plate; (4) the wilting point—retention of soil water at 15 atmos. on the pressure membrane after Richards; (5) coefficient of filtration after Darcy in cylinders of 100 cm^3 after Plamenac; (6) the values Y_1 by multiplying with the factor 0.65; (7) sum of adsorbed bases (S. meq) has been determined according to Kappan; (8) the degree of saturation with bases (V%) of the adsorptive complex has been determined by means of reckoning after Hissink; (9) the organic matter contents—by the permanganate method after Kotzman; (10) the contents of $CaCO_3$ after Scheibler; (11) nitrogen after Kjeldahl; (12) physiologically available phosphorus-extraction by lactate and determination after Egner; (13) available K_2O by ammonium oxalate and ammonium acetate after Schachtschabel; (14) exchangeable cations and CEC according to U.S.D.A. Manual No. 60 of 1954; (15) total boron by melting with Na_2CO_3 in a platinum

TABLE 1. Precipitation in growing season at experimental sites, mm

Experimental fields	Month and year													
	April		May		June		July		August		September		Total	
	1974	1975	1974	1975	1974	1975	1974	1975	1974	1975	1974	1975	1974	1975
Zlatibor	85.1	53.3	87.6	114.3	81.2	238.4	74.5	116.5	45.6	122.9	173.9	20.7	527.9	666.1
Suvobor	91.4	38.0	122.4	142.8	162.5	143.5	61.4	52.8	36.3	163.8	74.1	12.8	548.1	553.7
Ozren	27.0	28.4	80.2	141.7	70.3	84.8	29.4	43.2	25.7	101.2	50.1	42.0	282.7	441.3

container and determining after Jackson; (16) total Cu, Fe, Mn, Mo, Zn, in HF-H_2SO_4-$HCLO_4$ after Jackson; (17) available boron in hot water after Berger—Truog; (18) copper after Westerhoff in diluted HNO_3; (19) manganese after Schactschabel by sulfide method at pH 8.0; (20) molybdenum after Griegg by oxalate buffer pH 3.3; and (21) zinc after Wear-Sommer in 0.1 NKCl.

SOIL PROPERTIES

The soils of the experimental fields Zlatibor and Suvobor are developed on serpentine and belong to the order *Entisols*. These soils we call humus/silicate soils (Ranker). They are very shallow without genetic horizons. Although they belong to the same order, between these two soils there are also some differences. Thus, the humus/silicate soil of the experimental field Zlatibor doesn't contain as many fragments of undisintegrated rock as is the case with the soil of experimental field Suvobor. The soil of experimental field Ozren is formed from limestone and belongs to the rendzinas. It is characterized by a shallow profile of the Ap-C type. The humus/silicate soil and rendzina are characterized by a black color (2.5 YR 2/0), conditioned by considerable organic matter, minute granular structure, great porosity and permeability through one whole depth.

In Table 2 are given the results of analyses of texture of the soil in all three experimental fields. On the basis of these data, it can be assumed that the humus/silicate soil from Zlatibor and Suvobor is a sandy loam, and the rendzina from Ozren is quite unexpectedly of a lighter texture and characterized by a greater part of fine sand (over 65%).

The water properties of the soil of Zlatibor and Ozren are set forth in Table 3. From these data, it is not difficult to draw the conclusion that these soils are characterized by favorable water properties. However, in spite of favorable water properties, the plants suffer very often from water deficiency in summer months, for the soil is shallow and lies immediately on the solid parent material which warms up more quickly and stimulates a more intensive evapotranspiration.

The chemical properties of the experimental fields are set forth in Table 4. According to these results, the rendzina is characterized by a weak alkaline reaction and the humus/silicate soils by a weak

TABLE 2. Texture of soils

Locality	No. of experiment plot	Vegetation land use	Horizon	Depth, cm	Coarse sand >0.2 mm %	Fine sand 0.2-0.02 mm %	Silt 0.02-0.002 mm %	Clay <0.002 mm %	Total sand >0.02 mm %	Silt + clay <0.02 mm %
Ozren	10	pasture	A	0-19	1.0	73.6	7.4	18.0	74.6	25.4
	20	pasture	A	0-18	1.0	68.2	11.0	19.8	69.2	30.8
	30	pasture	A	0-27	0.0	74.2	10.2	15.6	74.2	25.8
	40	pasture	A	0-22	1.0	67.6	13.4	19.0	67.6	32.4
	50	pasture	A	0-15	0.0	55.4	13.2	20.4	66.4	33.6
Zlatibor	10	pasture	A	0-10	5.0	37.0	33.2	24.8	42.0	58.0
		pasture	A	10-20	8.0	36.6	33.8	21.6	44.6	55.4
	20	pasture	A	0-9	10.0	36.8	29.4	23.8	46.8	53.2
	30	pasture	A	0-11	5.0	37.0	31.8	26.0	42.2	57.8
		pasture		11-22	5.0	36.4	34.8	23.8	41.4	58.6
	40	pasture	A	0-13	7.0	38.4	30.8	23.8	45.4	54.6
	50	pasture	A	0-6	11.0	34.4	33.2	21.4	45.4	54.6
Suvobor	IC	pasture	A	0-15	8.0	28.0	44.0	20.0	36.0	64.0
	IIC	pasture	A	0-15	5.8	28.2	42.8	24.0	33.2	66.8
	IIIC	pasture	A	C-15	5.0	31.2	43.8	20.0	36.2	63.8
	IIC	pasture	A	0-15	0.0	47.6	35.0	17.4	47.6	52.4
	VC	pasture	A	0-15	6.0	34.0	40.8	19.2	40.0	60.0

TABLE 3. Water properties of soils

Locality	No. of profile	Depth cm	Hygroscopic moisture %	Volume weight g/cm³	Specific weight	Porosity	Maximum hygroscopic	Field capacity vol. %	Wilting point vol. %	Available water vol. %	Air capacity vol. %	Darcy's coefficient cm/sec
Zlatibor	2	0-9	9.0	0.87	2.50	65.2	64.0	43.4	28.4	15.0	21.8	5.8×10^{-4}
Ranker	4	0-13	9.6	0.86	2.46	65.0	63.8	43.6	28.5	15.1	21.4	8.4×10^{-4}
Ozren	2	0-18	4.6	1.10	2.53	56.5	55.4	35.1	21.1	14.0	21.4	2.3×10^{-3}
Rendzina	3	0-27	3.8	1.15	2.62	56.1	54.0	32.1	17.4	14.7	24.0	1.2×10^{-3}

TABLE 4. Chemical properties of soils

Locality	Experiment plot	Vegetation	Horizon	Depth cm	pH $CaCO_3$	pH H_2O	pH N KCL	Y_1 cm³	Adsorptive complex T-S meq/100	Adsorptive complex S meq/100	Adsorptive complex T meq/100	Adsorptive complex V%	Humus %	Total N%	Available P_2O_5 meq/100	Available K_2O meq/100
Ozren	10	pasture	A	0-19	71.38	7.90	7.45	—	—	—	—	—	8.43	0.60	16.0	5.6
	20	pasture	A	0-18	68.06	8.00	7.30	—	—	—	—	—	9.05	0.60	7.0	6.9
	30	pasture	A	0-27	72.62	8.05	7.45	—	—	—	—	—	8.42	0.48	6.0	4.8
	40	pasture	A	0-22	64.95	7.95	7.35	—	—	—	—	—	8.84	0.56	7.3	5.8
	50	pasture	A	0-15	65.15	7.85	7.30	—	—	—	—	—	8.88	0.68	7.3	8.3
Zlatibor	10	pasture	A	0-10	0.0	6.10	5.50	16.37	10.64	44.84	55.48	80.82	8.65	0.72	1.1	26.0
			A	10-20	0.0	6.45	5.60	12.65	8.22	42.52	50.74	83.79	7.74	0.57	1	21.8
	20	pasture	A	0-9	0.0	6.35	5.60	16.61	10.79	51.52	62.31	82.68	9.78	0.82	1.6	33.9
	10	pasture	A	0.11	0.0	6.35	5.75	17.71	11.51	59.92	71.23	83.84	9.69	0.73	2.0	20.6
			A	11-22	0.0	6.60	5.80	12.61	8.19	49.88	58.07	85.89	8.65	0.76	1.6	17.4
	40	pasture	A	0-13	0.0	6.70	5.80	12.37	8.04	49.12	57.16	85.93	8.47	0.75	1.9	19.0
	50	pasture	A	0-6	0.0	6.10	5.60	13.10	8.51	42.60	51.11	83.34	0.06	0.57	1	16.9
Suvobor	IC	pasture	A	0-15	0.0	6.60	6.00	8.65	5.62	56.12	61.74	90.90	7.23	0.50	0.0	6.9
	IIC	pasture	A	0-15	0.0	6.80	5.90	11.65	7.57	48.44	56.01	86.48	7.53	0.54	0.0	8.4
	IIIC	pasture	A	0-15	0.0	6.60	5.80	10.60	6.89	42.20	49.09	85.96	0.34	0.34	0.0	7.2
	IVC	pasture	A	0-15	0.0	6.70	5.90	9.23	5.99	55.84	61.83	90.31	7.94	0.51	0.0	6.9
	VC	pasture	A	0-15	1.0	6.70	5.75	14.33	9.31	43.28	52.59	82.29	7.43	0.45	0.0	8.0

acid one. Both soils are rich in organic matter but poor in available potassium and soluble phosphorus, and, consequently, these principal nutrients, as well as nitrogen, should be added as mineral fertilizers.

From exchangeable cations, as can be seen from the data set forth in Table 5, magnesium prevails in the humus/silicate soils.

The contents of trace elements in the soils are set forth in Table 6. The data concerning total and available quoted trace elements in the soil show that differences exist. For the evaluation of the supply of trace elements in the soil, the available quantities are of a greater importance than total ones.

The rendzina is not well supplied with available zinc, whereas both the humus/silicate soils are rich in this element. The available copper presents an analogous situation. All the investigated subplots on the rendzina show that it also has a poor content of manganese and, therefore, both its total and available forms are considerably less than those found on the humus/silicate soils.

The available molybdenum in the soils of the experimental fields lie chiefly within the limits of a medium supply.

The mobile iron in the rendzina, in relation to the humus/silicate soil, is markedly less, due to the fact that iron, in a way similar to manganese, at a pH above 6.5 forms insoluble higher oxides which are moderately or poorly available.

FLORISTIC-PHYTOTYPOLOGICAL ANALYSIS

In addition to the soil investigations, particular attention was paid, in 1976, to the floristic-phytotypological analysis, which is of great importance from the point of view of melioration of eroded pastures. This is a concise statement of the results of these investigations on the experiment fields "Zlatibor," "Suvobor," and "Ozren."

Experiment Field Zlatibor

With regard to typology of plant species, the experiment field Zlatibor is the integral part of

TABLE 5. Exchangeable cations in adsorptive complex of soils

No. of sample	No. of experiment plot	Locality	Depth cm	Ca meq/100	Ca %	Mg meq/100	Mg %	K meq/100	K %	Na meq/100	Na %	CEC meq/100
6	10	Zlatibor	0-10	12.25	23.46	23.25	44.54	0.57	1.09	0.15	0.28	52.20
7		Zlatibor	10-20	7.37	15.90	22.90	49.40	0.50	1.08	0.14	0.30	46.35
8	20	Zlatibor	0-9	10.25	20.01	25.35	49.51	0.70	1.36	0.14	0.27	51.20
9	30	Zlatibor	0-11	9.85	17.20	30.40	53.10	0.47	0.82	0.14	0.24	57.25
10		Zlatibor	11-22	7.80	14.02	30.65	55.10	0.42	0.75	0.12	0.21	55.62
10a	40	Zlatibor	0-13	11.12	21.30	27.25	52.20	0.45	0.86	0.14	0.27	52.20
10b	50	Zlatibor	0-6	9.60	22.79	19.50	46.29	0.40	0.95	0.12	0.28	42.12
11	IC	Suvobor	0-15	8.00	16.89	26.90	56.78	0.17	0.36	0.10	0.21	47.37
12	IIC	Suvobor	0-15	10.25	20.84	24.85	50.53	0.12	0.24	0.14	0.28	49.17
13	IIIC	Suvobor	0-15	6.90	16.38	22.10	52.46	0.20	0.47	0.10	0.23	42.12
14	IVC	Suvobor	0-15	6.65	13.52	28.10	57.14	0.20	0.41	0.10	0.20	49.17
15	VC	Suvobor	0-15	6.50	14.52	21.75	48.60	0.22	0.49	0.10	0.22	44.75

pastures on the serpentine substratum, secondarily originated in the zone of white and black pine forest (*Pinetum silvestris-nigrae Pavlović*). On the basis of the phytotypological analysis of the investigated community, it can be deduced that it represents the transition phase between two syngenetically connected associations—*Poëto molineri—Plantaginetum carinatae Pavlović* and the *Festuceto sulcatae—Potentilletum zlatiborensis Pavlović*, which were described for the first time on the terrains of the mountain Zlatibor. Both plant associations are characterized by the presence of a number of serpentinophytes—plants adapted to the life on a serpentine substratum, which occur very rarely in similar associations on the substrata of different mineralogical composition.

The following survey quotes the plant groups and their incidence for the last two years of investigation:

	1975	1976
Total number	96	115
thereof:		
Fam. Poaceae/grasses	16	17
Fam. Fabaceae/leguminous plants	14	16
Aromatic and poisonous species	11	10
Weeds	2	4
Other species	53	68

The above survey shows certain differences both as regards the number and the structure of plant species. In 1976, in comparison with 1975, their number increased from 96 to 115. The dominant species and builder of the community, however, is *Festuca sulcata*, which, according to its nutritive value, belongs to medium quality species. Further, as the result of modified ecological conditions—suspension of grazing and trampling, introduction of mineral fertilizers—there occurred a shifting among the species, which is undoubtedly of importance for the improvement of the botanic composition of pastures.

Of 16 species from the family *Poaceae* in 1975, there was observed in 1976 one more species—*Agrostis capillaris*—and this occurred on almost all test plots on which mineral fertilizers had been introduced. This species plays a great part in forming desirable meadows. *Vicia tenuifolia* and *Chamaespartium sigitale* are two new leguminous species which were not present in 1975. The change of numbers and covering of grasses and leguminous plants speaks convincingly of the process of reclamation of the pasture ground on which the experiments are carried out and particularly of those plots into which had been introduced larger amounts of NPK fertilizers.

Experiment Field Suvobor

This field is situated in the zone of Serbian beech forest also on the serpentine substratum—*Fagetum montanum serbicum Rudski* subas. *silicicolum Jovanović*. The field is located on extremely eroded terrain with an eastern exposure.

In comparison with the investigated plant genetic composition on the field Zlatibor, the plant association on the field Suvobor is composed of fewer plant species, as indicated in the following:

	1975	1976
Total number of species	75	98
thereof:		
Fam. *Poaceae*/grasses	11	15
Fam. *Fabaceae*/leguminous plants	16	18
Aromatic and poisonous species	6	10
Weeds	5	7
Other species	37	48

The markedly dominant specie and builder of the association is *Festuca sulcata*, which, by nutritive

TABLE 6. Contents of trace elements of soils

Type of soil	Variants of fertilization	pH in N KCL	Boron "B" Total (ppm)	Boron "B" Available (ppm)	Boron "B" % of the total	Zinc "Zn" Total (ppm)	Zinc "Zn" Available (ppm)	Zinc "Zn" % of the total	Copper "Cu" Total (ppm)	Copper "Cu" Available (ppm)	Copper "Cu" % of the total
1	2	3	4	5	6	7	8	9	10	11	12
	0	6.80	66.00	0.76	1.15	87.00	1.60	1.84	18.00	1.50	8.33
Rendzina	N_{40} P_{40} K_{40}	6.80	59.25	0.76	1.28	84.00	1.60	1.90	18.00	1.00	5.55
Ozren	P_{80} K_{80}	6.80	63.70	0.95	1.49	87.50	1.70	1.94	18.50	1.00	5.40
	N_{80} P_{80} K_{80}	6.80	65.00	0.95	1.46	85.00	1.60	1.88	18.40	1.20	6.52
	0	5.10	49.50	0.61	1.23	92.00	9.80	10.65	27.50	3.40	12.36
Humus sili-	N_{40} P_{40} K_{40}	5.70	42.50	0.61	1.43	94.50	9.80	10.37	28.50	3.50	12.28
cate soil	P_{80} K_{80}	5.55	45.00	0.44	0.98	94.50	7.80	8.25	28.00	3.40	12.14
Zlatibor	N_{80} P_{80} K_{80}	5.40	51.25	0.54	1.05	92.00	7.00	7.61	27.50	3.50	12.73
	N_{160} P_{160} K_{160}	5.60	50.00	0.47	0.94	93.00	8.20	8.82	27.50	3.50	12.73
	0	6.00	31.25	0.90	2.88	119.00	14.40	12.10	18.50	3.00	16.22
Humus sili-	N_{40} P_{40} K_{40}	6.00	30.50	0.57	1.87	123.00	13.00	10.57	18.00	3.20	17.78
cate soil	P_{80} K_{80}	5.90	32.70	0.41	1.25	118.00	11.00	9.32	18.00	4.50	25.00
Suvobor	N_{80} P_{80} K_{80}	6.00	32.50	0.39	1.20	119.00	11.60	9.75	18.00	3.50	19.44
	N_{160} P_{160} K_{160}	6.10	30.00	0.58	1.93	123.00	14.80	12.03	19.00	3.50	18.42
	0	6.80	38.00	0.39	10.26	0.70	0.19	27.14	56.24	4.37	0.008
Rendzina	N_{40} P_{40} K_{40}	6.80	26.00	0.31	8.61	0.75	0.16	21.35	56.75	6.25	0.011
Ozren	P_{80} K_{80}	6.80	38.50	0.29	7.53	0.70	0.12	17.14	56.25	4.75	0.008
	N_{80} P_{80} K_{80}	6.80	36.00	0.20	5.55	0.76	0.14	18.32	56.25	5.00	0.009
	N_{160} P_{160} K_{160}	6.90	38.00	0.29	7.63	0.72	0.16	22.22	56.25	4.37	0.008
	0	5.90	17.50	13.40	7.66	0.64	0.06	9.37	23.50	84.37	0.36
Humus sili-	N_{40} P_{40} K_{40}	5.70	18.00	13.40	7.44	0.67	0.07	10.45	24.00	58.75	0.24
cate soil	P_{80} K_{80}	5.55	18.50	11.70	6.32	0.62	0.06	9.68	24.75	62.50	0.25
Zlatibor	N_{80} P_{80} K_{80}	5.40	19.00	14.20	7.47	0.64	0.10	15.62	24.50	71.87	0.29
	N_{160} P_{160} K_{160}	5.60	19.50	16.20	8.31	0.63	0.06	9.52	24.00	92.50	0.39
	0	6.00	19.00	13.00	6.84	0.69	0.07	10.14	16.00	62.50	0.39
Humus sili-	N_{40} P_{40} K_{40}	6.00	19.50	14.60	7.49	0.78	0.08	10.26	15.75	84.37	0.54
cate soil	P_{80} K_{80}	5.90	18.30	12.50	6.83	0.76	0.07	9.21	16.75	71.87	0.43
Suvobor	N_{80} P_{80} K_{80}	6.00	19.10	15.50	8.11	0.80	0.10	12.50	16.50	96.87	0.59
	N_{160} P_{160} K_{160}	6.10	19.50	15.50	7.95	0.76	0.10	13.60	16.00	58.12	0.36

value, belongs to medium quality grasses. The next species with greatest numbers are *Thymus jankae* subvar. *servicus* and the bushy plant of the carnation family, *Minuartia verna* subsp. *collina*.

The modified ecological conditions on the experiment field which had been previously dealt with exerted an influence on the change of the floristic structure of the association of this experiment field, a change which gradually moves in the direction of improvement. Changes among the species both grasses and leguminous plants have great importance, particularly the occurrence of bush xerophilous species adapted to the poor dry and warm habitat of the rocky ground because they offer good protection against the erosion to the soil and cover the denuded surfaces.

Experiment Field Ozren

From the phytotypological point of view, the experiment field Ozren is very similar to the association described for this mountain—Poterieto—*Festuceatum vallesiaceae Danon* subas. *Koelerietosum Diklić*. This association is a somewhat more xerophilous type, which is otherwise very widespread on the mountain Ozren, where it inhabits comparatively warm, dry and abrupt habitats of western, eastern, and southern exposures.

On account of permanent and excessive grazing from early spring until late autumn, the mesophilous plant species are strongly reduced to a minimum. Maintaining itself is only the builder of the association, the fescue *Festuca vallesiaca* together with some

weeds, aromatic or poisonous species. Below is the survey of plant species according to groups:

	1975	1976
Total number of species	102	132
thereof:		
Fam. *Poaceae*/grasses	9	15
Fam. *Fabaceae*/leguminous plants	10	16
Aromatic and poisonous plants	17	20
Weeds	10	13
Other species	56	68

Among the grasses, the most important species is undoubtedly *Festuca vallesiaca*, which shows also the highest degree of presence in the association and the greatest numbers and covering, and, consequently, also the greatest biomass. This species, according to criteria which are valid in meadow management, belongs, according to its nutritive value, to medium quality grasses. *Poa pratensis* and its subspecie *angustifolia* are considered, according to the same criteria, as grasses with a very good nutritive value. A considerable part in the building up of the association is played also by *Poa bilbosa*, *Koeleria gracilis*, *Poa alpina* subsp. *badensis* and, in a somewhat less measure, by *Dactylis glomerata*, *Poa compressa* and some other species.

In the course of 1976, the floristic structure on test plots underwent noticeable changes. The number of species was increased from 102 to 132 and a particularly important fact is that the number of grasses increased by six species along with an increase in the number of leguminous plants, which play a considerable part in the improvement of the nutritive value of the pasture. Worth mentioning among them are *Medicago lupulina*, *Onobrychis sativa*, *Trifolium incarnatum*, which appear for the first time on a large number of test plots.

After three years of introduction of mineral fertilizers on the experiment field Ozren there was observed, as on the other two fields, a high degree of increase of mesophilous character of the association as a whole and, thereby, also the reclamation of eroded pastures on which the experiments were carried out.

The analysis of the floristic composition of the test plots, and analyses of fertilizer with different amounts of NPK used at different times allowed us to draw the preliminary conclusion that greater amounts of nitrogen introduced in the beginning of vegetation stimulated the growth of grass species, while larger doses of potassium favored legumes, particularly *Lotus corniculatus* and *Trifolium repens* and *T. pratense*. Further, it can be ascertained that on the experimental fields, as well as on the pastures where there is free grazing, there are many species growing that have no value at all from the point of view of cattle fodder.

EFFECT OF FERTILIZATION ON VEGETATION, FODDER PRODUCTION AND SOIL EROSION

Methods of Work

On the experimental fields we investigated the influence of the quantity of introduced mineral fertilizers and the influence of the time of their introduction on the yield and on some qualitative properties of the plant mass on eroded pastures. The experiments were laid in five replications on test plots of 15 m^2 each.

The investigations were carried out with 13 variants of fertilizers in kg/ha as shown below:

1.	$P_{40}K_{40}$	8.	$N_{40}K_{40}P_{80}$
2.	$P_{40}K_{40}N_{40}$	9.	$N_{40}K_{40}P_{160}$
3.	$P_{40}K_{40}N_{80}$	10.	$N_{40}P_{40}$
4.	$P_{80}K_{80}$	11.	$N_{41}P_{40}K_{80}$
5.	$P_{80}K_{80}N_{80}$	12.	$N_{40}P_{40}K_{160}$
6.	$P_{80}K_{80}N_{160}$	13.	$N_{160}P_{160}K_{160}$
7.	$N_{40}K_{40}$	14.	O (no fertilizer)

The time of application was as follows:

A. The whole amount of mineral fertilizers introduced at once, before the beginning of vegetative period, in the first days of March;

B. The whole amount of mineral fertilizers in one application at the end of April;

C. The total amount of fertilizers applied in the course of growth, at the end of June, after the first mowing;

D. The fertilizers applied twice: ½ before the beginning of growth and ½ in the course of growth;

E. The fertilizers applied at three intervals: ½ before the beginning of growth, ¼ in the beginning of growth and ¼ in the course of growth.

In order to ascertain the percentage of dry matter and to get chemical analyses, plant samples were taken from all variants of fertilizing where mineral nutrients had been introduced once only at the beginning of vegetation. Yields were tested by variance analysis, applying the LSD Test.

RESULTS AND DISCUSSION

Two years' average yield of the plant mass (Table 7) point out both the importance of applying various quantities of mineral fertilizers and the importance of the time of application. It is obvious from the first year yield analysis that single introductions of fertilizers before vegetation started and in the beginning of vegetation have given yields which were almost twice as large as those obtained by the introduction of fertilizers in the course of growth. This is understandable considering the diminished amounts of rainfall in summer months in which the effect of later introduced fertilizers is limited and the conditions for their losses until the following growing period are considerably larger. The yields

TABLE 7. Influence of amount and the time of use of fertilizers on the yield of hay mc/ha

Time of fertilizer use	Variants of fertilization														LSD	
	0	$P_{40}K_{40}$	$P_{40}K_{40}N_{40}$	$P_{40}K_{40}N_{80}$	$P_{80}K_{80}$	$P_{80}K_{80}N_{80}$	$P_{80}K_{80}N_{100}$	$N_{40}K_{40}$	$N_{40}K_{40}P_{80}$	$N_{40}K_{40}P_{100}$	$N_{40}P_{40}$	$N_{40}P_{40}K_{80}$	$N_{40}P_{40}K_{100}$	$N_{100}P_{100}K_{100}$	0.05	0.01
							Zlatibor									
A	11.3	22.9	27.6	33.4	27.2	41.5	57.3	15.3	34.5	29.5	19.3	29.4	23.3	68.4	13.7	18.3
B	11.5	23.4	31.7	33.4	26.7	38.8	64.1	14.1	35.0	34.6	22.7	27.9	26.3	60.6	14.4	19.3
C	11.1	14.3	22.3	18.9	19.3	21.9	29.1	11.6	21.1	27.8	11.9	20.0	16.8	31.6	8.5	11.3
D	10.0	15.7	26.7	27.6	26.2	34.7	48.1	9.4	22.6	29.1	19.5	22.2	21.8	42.8	9.8	13.2
E	9.7	21.2	30.9	30.9	28.6	37.2	55.5	12.8	29.8	37.3	22.6	28.3	24.7	61.7	15.6	20.8
							Suvobor									
A	2.0	14.3	14.3	28.5	9.2	28.7	67.7	8.1	18.9	20.0	18.8	14.4	19.5	58.0	12.4	16.6
B	2.2	12.6	14.2	26.6	11.6	34.3	49.7	7.2	23.1	21.7	16.9	20.3	21.1	51.0	10.8	14.5
C	2.3	7.6	7.1	12.4	6.6	16.5	27.6	4.8	13.0	9.5	10.7	9.3	14.7	22.4	7.3	9.8
D	2.7	12.7	11.0	20.9	8.4	28.3	44.2	6.4	15.3	13.9	13.3	12.1	16.7	46.1	9.9	13.3
E	2.9	12.8	12.3	23.8	9.1	32.5	47.5	8.8	22.4	16.8	13.1	13.0	15.9	58.4	10.0	13.4
							Ozren									
A	5.7	7.1	20.6	32.0	9.1	32.3	58.4	14.5	18.2	20.5	21.1	21.0	16.7	52.0	8.0	10.8
B	4.6	6.7	20.0	28.7	9.2	27.7	52.5	11.3	19.1	18.0	23.1	26.7	17.5	51.5	6.0	8.0
C	5.2	6.4	10.8	15.7	7.2	15.1	24.4	9.1	11.2	10.2	11.0	11.7	11.0	22.4	5.2	6.9
D	5.0	6.5	11.6	30.0	10.5	25.4	41.6	11.2	9.2	16.5	16.0	14.7	14.4	41.0	7.5	10.0
E	4.2	7.1	15.0	28.3	9.9	27.1	45.9	13.1	15.7	17.1	15.8	16.4	18.0	50.0	7.8	10.5

of the plant mass in two other methods of application—where the mineral fertilizers were added in different quantities before and in the course of growth—are somewhat lower, which also indicates the advantage of introducing the total amount of fertilizers earlier in the spring when there is already far more moisture in the soil for their mobilization.

Various mineral fertilizers manifested different effects on the yield of the plant mass. Differences obtained in the tests between individual variants of fertilizers are a consequence both of different quantities and of different ratios between the nutrients. From the results, it can be seen that nitrogen produces the greatest effect, a little more than of phosphorus and considerably more than the effect of potassium. Nitrogen produced a marked effect up to 160 kg/ha. The increases of yields in the variants with N_{160} in relation to the check were from 6-fold in the Zlatibor site to 20-fold in the Suvobor site. These increases are statistically very significant with the single applications, i.e., *A* and *B*, and they amount to over 50 mc/ha of hay. Almost all introductions of fertilizers of variants 14, 7, 6, 4, 9 and 10 have given highly significant increases of yields, whereas the increase of yields in variants 2, 8 and 11 was generally very small and statistically insignificant. It can be seen from these results that the dominant nutrient for stimulating yields in these experimental fields was nitrogen, in the amount of 80–160 kg/ha, but phosphorus and potassium also had positive effects which may be observed chiefly at levels up to 80 kg/ha.

The uniform introduction of small quantities of nitrogen with potassium and without phosphorus had little effect on the plant mass yield.

The influence of phosphorus, though considerably less than the effect of nitrogen, is statistically justified and the yields obtained in the experiments at Zlatibor and Suvobor are up to two times or about 15 mc/ha greater in relation to the $N_{40}K_{40}$ variant. A somewhat smaller effect of phosphorus is observed at the experimental site Ozren, where the soil is better supplied with the available form of this element.

The effect of potassium is noticeable in some cases up to K_{80}, but chiefly statistically insignificant. Such a limited effect of potassium can be understandable, because these soils are for the most part medium to well supplied with this nutrient.

It was ascertained by chemical analyses that the fertilizers showed a considerable influence on plant quality which resulted for the following reasons: change in content of substances in the plants themselves which originated under the influence of greater or smaller quantities of nitrogen, phosphorus or potassium components introduced into the soil plus the change in the proportions of leguminosae and gramineae in the yield caused by the kind and quantity of each particular nutrient.

TABLE 8. Influence of the fertilizers on the content of crude protein and cellulose in the hay

Variants of fertilization	Zlatibor				Suvobor				Ozren			
	Protein %	Index	Cellulose %	Index	Protein %	Index	Cellulose %	Index	Protein %	Index	Cellulose %	Index
0	10.1		30.1		7.3		29.5		7.9		29.3	
$P_{40}K_{40}$	12.5	100	27.0	100	11.0	100	27.9	100	10.5	100	26.1	100
$P_{40}K_{40}N_{40}$	9.6	76	29.9	111	7.9	72	32.2	115	8.2	78	31.4	120
$P_{40}K_{40}N_{80}$	11.2	89	32.0	118	10.2	93	30.1	108	10.7	103	29.5	113
$P_{80}K_{80}$	15.8	100	25.5	100	9.5	100	30.2	100	8.7	100	28.8	100
$P_{80}K_{80}N_{80}$	6.9	43	36.2	142	9.9	104	31.2	103	10.0	115	30.2	105
$P_{80}K_{80}N_{160}$	10.7	67	34.5	135	11.9	125	29.2	97	13.4	154	28.9	100
$N_{40}K_{40}$	7.7	100	34.8	100	11.2	100	29.3	100	9.6	100	27.4	100
$N_{40}K_{40}P_{80}$	9.4	122	32.1	92	9.4	84	32.5	111	9.4	98	27.7	97
$N_{40}K_{40}P_{160}$	13.1	170	28.1	81	8.7	78	32.5	111	9.2	96	28.4	100
$P_{40}K_{40}$	9.8	100	31.2	100	9.7	100	30.5	100	9.8	100	29.8	100
$N_{40}P_{40}K_{40}$	10.1	103	30.8	99	6.9	71	34.3	112	8.3	85	29.6	99
$N_{40}P_{40}K_{160}$	9.4	95	32.7	105	8.4	87	31.6	104	8.7	89	31.3	105
$N_{160}P_{160}K_{160}$	9.8		34.1		7.4		32.8		10.9		33.3	

Judging by the results of double combinations, all of the three introduced elements in lower quantities (40 kg/ha) increased the percent contents of crude protein in hay. It is necessary to point out that where phosphorus fertilizers had markedly increased the proportion of leguminous plants in the hay, the percent protein content with PK is the greatest (Zlatibor). On those pastures where the phosphorus-potassium component had a less important influence on the increase of leguminosae, the positive effect of nitrogen on the percentage of crude proteins in the hay of the grass-leguminous mixture (Suvobor, Ozren) still cannot be neglected.

Nitrogen and potassium fertilizers increased the contents of the crude fiber, and the quantity of these organic substances is considerably greater in all variants where the nitrogen-potassium component had been applied. Though the key factor for the quantity of cellulose is the development stage of the plant, the greater mass of ligneous grass species whose development in the first summer months was furthered by nitrogen had considerable repercussion on the established quantity of these substances in the plant mass.

CONCLUSIONS

Mineral fertilizers, applied at different times, showed a different effect on the plant yield on all of the three experimental sites. These differences are due both to different amounts and ratios of nutrients in the introduced mineral fertilizers and to the time of their introduction.

Nitrogen component caused the greatest response, the phosphorus component somewhat less and the potassium component the least response. With the quantities N_{80-160} plus $P_{80}K_{80}$ kg/ha up to 20 times greater yields than control plots were obtained.

The most appropriate time and methods of applying the mineral fertilizers are the single introductions before growth starts or during early growth (March–May).

The introduction of mineral fertilizers improves the floristic composition of eroded pastures and the qualitative and nutritive value of the plant mass.

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76.
The Selection and Breeding of Plants Adapted to Low Fertility and Toxic Soils

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When soil conditions are extreme there are two options open to the agronomist who wishes to establish pasture or other vegetation cover: improvement of the soil by draining, liming, or fertilizing, etc.; the use of plants tolerant of the conditions existing in the soil in its unimproved state.

Which option is used depends on a number of factors. In agricultural areas, since an economic output is required and improvement is usually feasible, improvement is undertaken. Normal agricultural species and varieties which have no special tolerances then can be used because the improvements will have raised the fertility and physical structure of the soil to levels on which normal agricultural varieties can thrive.

However, on land being reclaimed for agriculture in extreme conditions such as can occur on hill land, these improvements may not be practical or may not be very permanent. In some cases it may be uneconomical to carry out a full improvement. The same is true with reclamation of derelict land, where, for instance, there is extreme acidity due to oxidation of pyrite. On such land, liming can effect a considerable improvement, but the acidity and attendant problems may return later when further pyrite is oxidized. Where the derelict land contains heavy metals, the problem is most marked. It may be impossible to get rid of the effects of heavy metals when they are at high concentrations. Organic matter, such as sewage sludge or heavy fertilizer treatments especially high in phosphorus, can render the metals unavailable for a short time, but the toxicity returns subsequently (Goodman *et al.*, 1973). The other derelict land where soil improvement is extremely difficult is where there is high salinity, usually due to weathering of sulphide materials in the presence of native carbonates, especially magnesium carbonate, which gives rise to magnesium sulphate.

In these situations species and varieties adapted to normal agricultural conditions will be unsuccessful. They may fail to grow altogether, or at best grow very poorly. The only practical solution is to find plant material which is specifically adapted to the difficult conditions. There are now many situations in the world where this can occur, both because agricultural operations are being extended into difficult environments such as hill land, and because industrial activity is leading to extensions of mining and metal processing.

The purpose of this paper is to examine the approaches that can be taken in finding or developing plants with specific tolerances to extreme soil conditions, particularly in relationship to low levels of plant nutrients and to high levels of toxic metals.

ADAPTATION TO LOW FERTILITY

We are familiar with the fact that different species can possess markedly different tolerances to difficult environmental conditions. In the grasses that occupy natural habitats in Great Britain, there is a wide range of tolerances to soil pH (Table 1). The species are in fact responding only in part to the direct effects of pH. The major differences among them are in their tolerances to the secondary effects of pH such as high Al and Mn at low pH, high Ca and low P and Fe at high pH. At the same time, there are effects arising from competition which cause species such as *Festuca ovina* often to be excluded from soils of intermediate pH.

This range of variability between species can be utilized in revegetation programs. In practice, it is not used to a great extent because of the difficulty of obtaining seed of the species adapted to extreme soil conditions, and because if improvement is carried out, it is usually preferable to seed higher yielding species such as *Lolium perenne*. But in these circumstances, we may find there is rapid deterioration of the sward and invasion by native species tolerant to the poor conditions, such as *Agrostis tenuis*. It would be valuable if material of species such as *Lolium perenne* could be found which was tolerant to difficult conditions.

Many of the species shown in Table 1 appear to have a wide range of tolerance since they can be found growing in a range of different soils. The extreme perhaps is *Festuca ovina*. This wide range of tolerance could be due to a wide physiological tolerance of individual plants of the species or to the evolution of local populations or races closely adapted to local conditions. The breadth of tolerance could be due to phenotypic or genetic plasticity.

TABLE 1. The range of soil pH tolerance of a number of grassland species in 630 sites in the Sheffield area of England (from Grime and Lloyd, 1973) (measured as % frequency of occurrence in each pH class)

Species	pH at Soil Surface 3	4	5	6	7-8
	Frequency of occurrence				
Agrostis tenuis	30-50	50-100	50-100	30-50	5-10
Arrhenatherum elatius	>5	10-30	30-50	30-50	10-30
Brachypodium pinnatum		>5	10-30	10-30	10-30
Briza media		5-10	10-30	30-50	30-50
Dactylis glomerata	>5	30-50	50-100	30-50	50-100
Deschampsia flexuosa	50-100	30-50	10-30	>5	>5
Festuca ovina	50-100	50-100	50-100	50-100	30-50
Helictotrichon pubescens		>5	30-50	30-50	10-30
Holcus lanatus	>5	50-100	50-100	30-50	30-50
Nardus stricta	30-50	10-30	>5		
Trifolium repens	>5	10-30	30-50	10-30	10-30
Zerna erecta		>5	5-10	10-30	30-50

We are familiar with the amount of evolutionary divergence in morphological characters that can take place within a species. Since edaphic factors are potentially very powerful in their selective effects, it seems possible that the wide edaphic tolerance of species could be due to a similar evolution of locally adapted populations. This is clearly true in the case of *Festuca ovina* (Fig. 1) (Snaydon and Bradshaw, 1961).

We have, therefore, investigated a range of pasture species common in the British Isles, and widely used in temperate regions: wild white clover (*Trifolium repens*) (Snaydon and Bradshaw, 1962a, 1969), rye-grass (*Lolium perenne*) and orchard grass (*Dactylis glomerata*) (Crossley and Bradshaw, 1968). These are species known to contain a wide range of morphological variability but for which no variation in response to soil fertility has been reported.

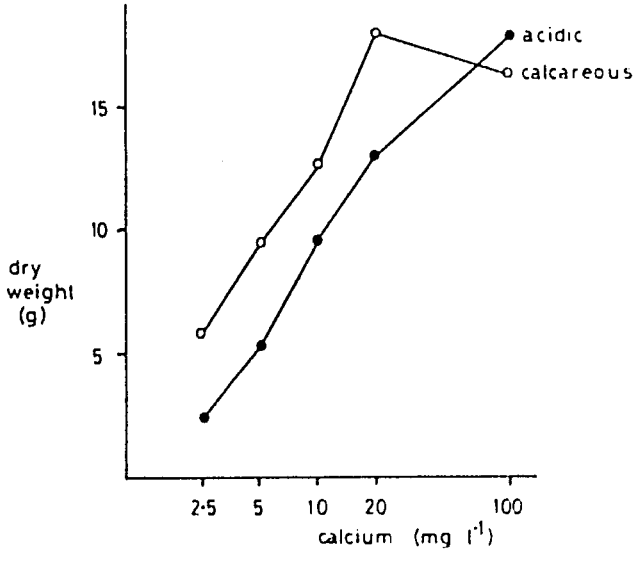

Figure 1. The response of two contrasting populations of the grass *Festuca ovina* to varying levels of calcium in sand culture (Snaydon and Bradshaw, 1961).

The initial experiments were carried out in sand culture so that nutrient levels could be carefully defined. These showed that considerable differences among populations in their response to varying levels of phosphorus and calcium can be found in all three species. Populations from low calcium and low phosphorus sites are able to tolerate lower levels of these elements in culture solution than other populations, tolerance being shown by only a small reduction in yield. This can be seen for example in *Dactylis* for phosphorus (Fig. 2). The relationship is particularly well shown in *Trifolium repens* for phosphorus (Fig. 3). In this experiment, the *Trifolium repens* populations were in fact subjected to a further higher level of phosphorus. At this level there were signs of phosphorus toxicity and reductions in yield. This was most marked in populations from calcareous sites and least in those from acidic sites. This can be related to the fact that in calcareous sites phosphate availability is always low because of the effects of high calcium, whereas in more acidic sites phosphorus availability is not reduced.

Where plant analysis has been carried out in *Festuca ovina* and *Trifolium repens*, the populations which are best able to tolerate low levels of a particular nutrient have a higher internal concentration of the nutrient. The ability to grow at low nutrient levels is therefore related to the efficiency of nutrient uptake.

These differences could be rather academic if they were not also manifest in more natural soil conditions. Experiments with all four species show that

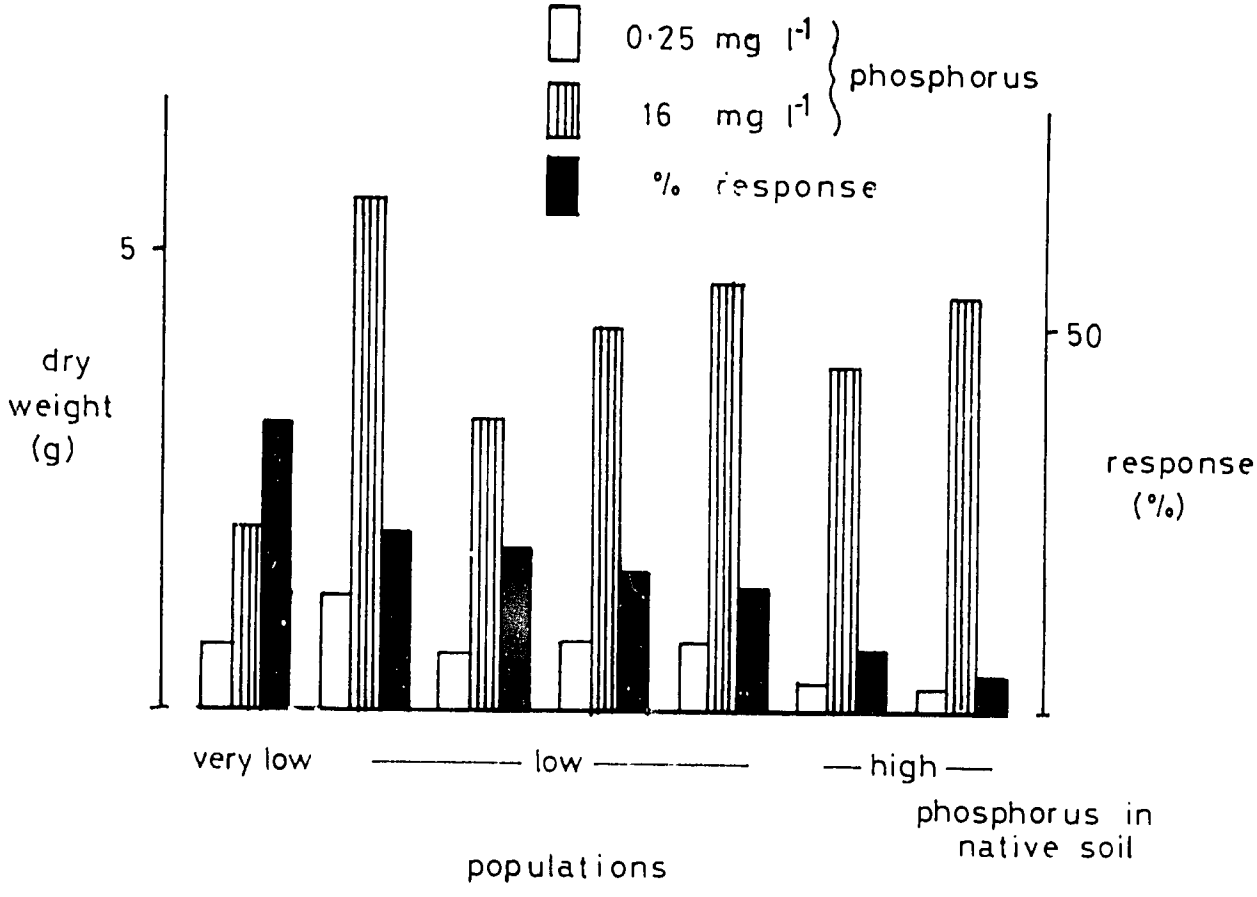

Figure 2. The response of a range of populations of the grass *Dactylis glomerata* to two levels of phosphorus in sand culture (Crossley and Bradshaw, 1968).

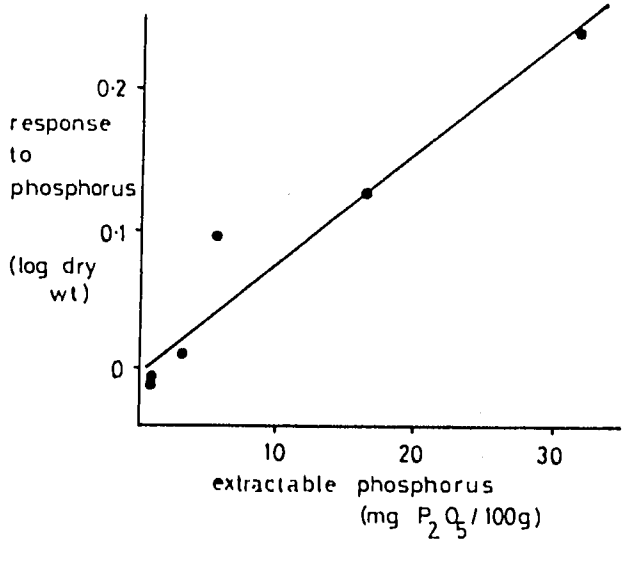

Figure 3. The relationship between the response of a range of populations of *Trifolium repens* to two levels of phosphorus in sand culture and the extractable phosphorus levels in their original habitats (Snaydon and Bradshaw, 1962a).

the results found in sand culture also appear in soil experiments, for instance, in *Dactylis* (Fig. 4). These differences are enhanced when the populations are grown in competition so that differences which appear trivial when the populations are grown alone become marked when there is competition (Snaydon, 1962).

But perhaps the critical test is the performance of the populations in natural conditions. In experiments with white clover, populations were planted into a natural upland sward and left to be subject to the full range of environmental pressures of the habitat. In these conditions there was markedly better survival by the upland populations which are tolerant of low nutrient conditions (Snaydon and Bradshaw, 1962b). However, when lime was added, this difference disappeared, indicating that the significant adaptation of the upland population is in its nutrition (Bradshaw, 1969).

Such differences between populations are therefore very important to survival. This is borne out by further work on *Anthoxanthum odoratum* (Snaydon, 1970). All this suggests that much of the lack of success in establishing improved pastures on

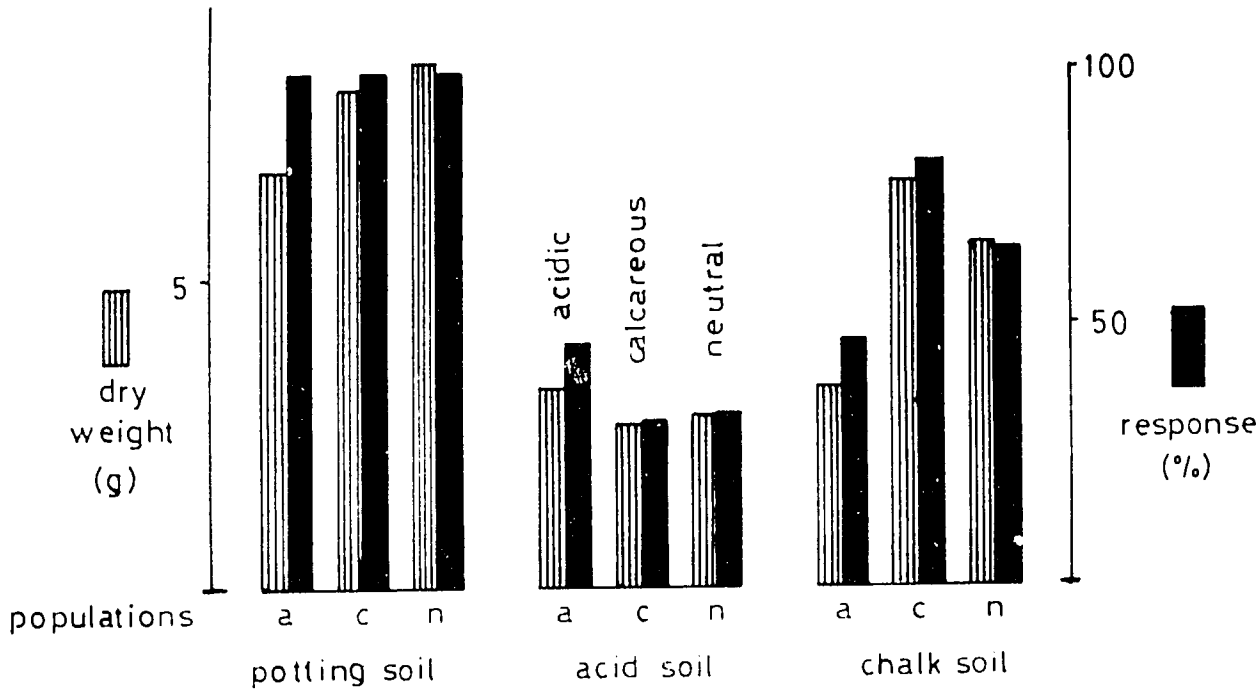

Figure 4. The growth of contrasting populations of *Dactylis glomerata* in three different soils (Crossley and Bradshaw, 1968).

difficult soils may be due to the use of commercial varieties which have been bred for high yield in high nutrient conditions.

Once it has been identified, the material will probably require some simple selection for seed production and related agronomic traits. It then can be bulked up and used directly for the revegetation of difficult areas. However, the material can equally well be used as the basis of a selection program in which the adaptation to low fertility is further developed. There is evidence in *Festuca ovina*, *Trifolium repens*, and *Dactylis glomerata* of substantial variability between individual genotypes in their yield and their response to soil conditions, particularly in seed material (Fig. 5). It seems likely that this is determined to a large extent by additive genetic variations and, therefore, can be used in a selection program.

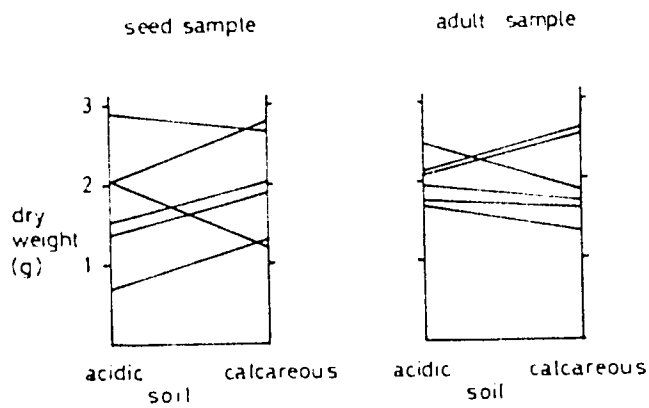

Figure 5. The contrasting responses to acid and calcareous soils of different genotypes of a population of *Dactylis glomerata* (a) derived from seed sample; (b) derived from tiller sample (Crossley and Bradshaw, 1968).

ADAPTATION TO HEAVY METAL TOXICITY

Toxic metalliferous soils occur widely in both temperate and tropical regions. They often are the result of recent mining activity, but there are some areas where the toxicity is of ancient origin and there has been no subsequent disturbance of the soil by glaciation or other factors. They provide very extreme types of environment and, therefore, strong selection pressures. So it is not surprising that a considerable amount of evolution in response to metal contamination has taken place in a wide range of plant species, leading to the development of metal tolerance.

The evolution of metal tolerance has now been well studied and forms one of the best examples of evolution in plants. The work was recently reviewed by Antonovics *et al.* (1971). In all the cases that have been studied, metal tolerance is found to be a property of particular populations of species, those growing on metalliferous soils, and not a property of whole species. It appears to evolve rapidly in response to the occurrence of metal contamination; considerable tolerance can appear in

populations of a perennial grass species such as *Agrostis stolonifera* in five years (Wu *et al.*, 1975). Artificial selection experiments show that tolerance can be selected in a single generation (Walley *et al.*, 1974). However, this only can occur if the necessary variation is present in the base population (Gartside and McNeilly, 1974). It appears that those species which do not possess this variation do not evolve tolerance, even in natural situations.

Metal tolerance has been studied mainly by the use of root growth in solutions containing the heavy metal. Tolerant plants will continue root growth at metal concentrations which inhibit the root growth of non-tolerant plants. This characteristic is not a trivial one. It is the major characteristic of metal tolerance and leads to the survival of tolerant plants in metal contaminated soils and the death of other, normal, material. If seeds of normal non-tolerant plants are sown on metal contaminated soil, they will usually germinate and develop a coleoptile or shoot. However, the plants rapidly fall over and die because root growth is inhibited. On less toxic soils, the plants may grow for some time and produce roots, but they die later because of an accumulation in the plant of toxic concentrations of metal. In contrast, metal tolerant material roots and grows normally. If the soil is very deficient in plant nutrients, which is likely in most mine wastes, appropriate amounts of fertilizer must be added or the growth even of tolerant material will be restricted. The superiority of metal tolerant materials, especially when supplied with fertilizer, is exemplified in Fig. 6, for a lead and zinc contaminated site (Smith and Bradshaw, 1972).

Metal tolerant material is clearly of considerable value in metal contaminated situations. It allows a plant cover to be established directly on mine waste using only fertilizer, without the use of top soil or other inert material as a cover. Metal tolerance is, however, fairly specific for individual metals, although a certain amount of cross tolerance does occur (Jowett, 1958; Bradshaw, 1976) (Fig. 7). This means that metal tolerant material must be chosen in relation to the metal contamination of the site being revegetated.

The value of metal tolerant material has been demonstrated in the pioneering reclamation work in the derelict areas of smelter waste in the Lower Swansea Valley, S. Wales. It was originally shown that vegetation could be effectively established on copper and zinc smelter wastes using normal herbage species if the wastes were first covered with a deep layer of sewage sludge or town refuse (Street and Goodman, 1967). But further work has shown that this is effective only for about five years, after which the metal contamination reappears at the surface and the sward deteriorates. However, in this situation, copper and zinc tolerant populations of bent

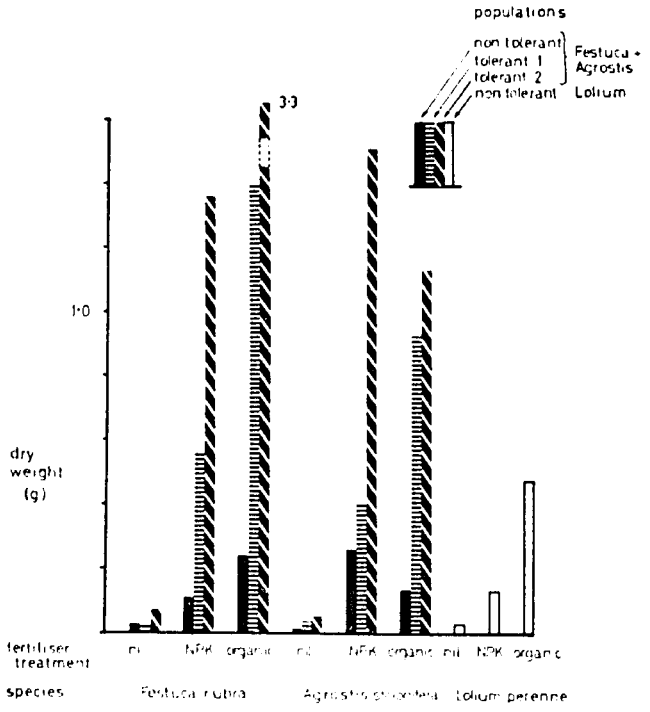

Figure 6. The growth of different tolerant and non-tolerant populations of *Festuca rubra* and *Agrostis stolonifera* compared with *Lolium perenne* (non-tolerant) on a lead/zinc mine with and without fertilizer (Smith and Bradshaw, 1972).

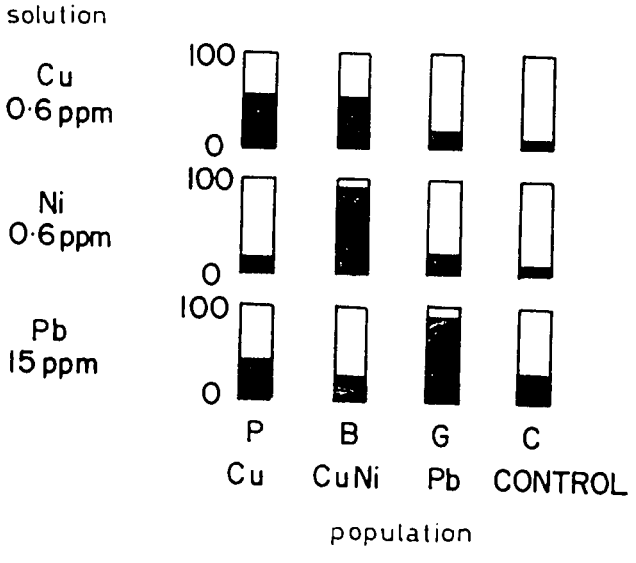

Figure 7. The index of tolerance to different heavy metals of various populations of *Agrostis tenuis* (Jowett, 1958) (index of tolerance measured as root growth in metal solution/root growth in normal solution).

grass (*Agrostis tenuis*) continue growing successfully. In particular, root growth is excellent in the tolerant material (Goodman *et al.*, 1973).

There are many metal contaminated areas on

which metal tolerance has evolved, and these are potential sources of useful material. In Britain, lead/zinc metal deposits are scattered widely in Wales, N. England and Scotland. The relative amounts of lead and zinc in the spoil vary, but levels of 1% of each are not uncommon. On these spoils, various plant species can be found, notably the two grass genera *Agrostis* and *Festuca*. Various early investigations (referred to by Antonovics *et al.*, 1971) have shown that these populations are metal tolerant. An extensive series of trials was therefore carried out to assess the value of these populations for reclamation purposes using a wide range of sites (Smith and Bradshaw, 1972). Some of the results for red fescue (*Festuca rubra*) are given in Fig. 8. These show that although commercial non-tolerant

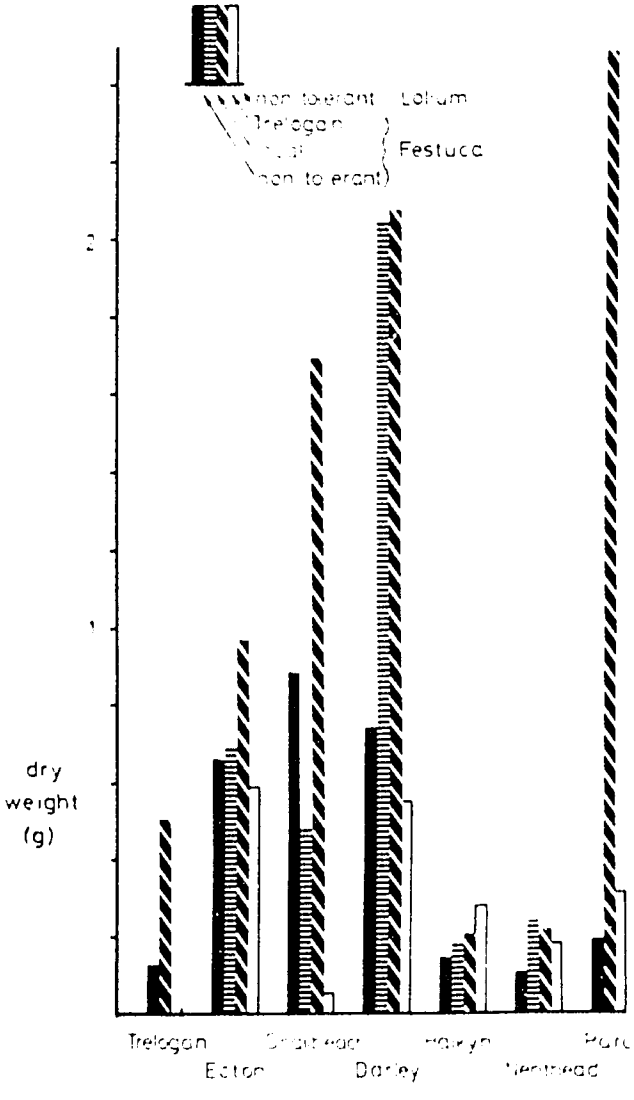

Figure 8. The growth on different lead/zinc mines of different populations of *Festuca rubra* (the local population is derived from the site of the trial) compared with *Lolium perenne* (non-tolerant) (Smith and Bradshaw, 1972).

material will grow on some sites, it is usually far inferior to both local material of the same species from the site (where available) and material from Trelogan, a site known to have a population with high lead and zinc tolerance (Smith and Bradshaw, 1972).

From this work one population of *Festuca rubra* from Trelogan has been identified as growing very successfully on all sites. This has become the basis, after some further selection, of the variety "Merlin" which now is commercially available for use on calcareous lead/zinc contaminated sites. It has been found to grow successfully even where the site is extreme, in other ways besides metal toxicity—for instance, where there is instability because of fine particle size of the material or steepness of slope. Indeed, its superiority is even more marked in these situations because of its ability to root rapidly and deeply. It is likely that part of this superiority is because of ability to tolerate low levels of major plant nutrients. This has been shown in lead tolerant material of *Agrostis tenuis* (Jowett, 1959).

Festuca rubra occurs naturally on calcareous or neutral soils only. For acid lead/zinc contaminated sites, lead/zinc tolerant material of bent grass (*Agrostis tenuis*) has been developed by the same methods. For copper contaminated sites, copper tolerant material of *Agrostis tenuis* has been developed. These two are now commercially available as the varieties "Goginan" and "Parys," respectively. Large quantities of seed have only become available this year, but large-scale trials of all three varieties show that they have outstanding persistence in metal contaminated areas. Some fertilizing is necessary to insure the build-up of major plant nutrients, but this can be kept to a low level (about 50 kg/ha of N and 25 kg/ha of P and K per annum).

Such material exemplified the potential that is available in breeding plants for metal contaminated, or indeed other, situations. It is not possible for one variety to be successful in all environmental situations, any more than in normal agriculture. However, metal tolerance is known to occur very widely in many differing grass and legume species, in temperate and tropical climates (for review of occurrence see Antonovics *et al.*, 1971). These populations should be identified and used.

Selection experiments have shown that if the variability is present in normal populations of a species, it can be selected very rapidly. It could, therefore, be worthwhile screening species already adapted to a particular region to see if useful metal tolerance is available. The screening technique is extremely simple—it merely involves sowing large numbers of seeds of the species on the appropriate metal contaminated soil and retaining those plants which are alive at the end of six months (Fig. 9). These can then be put into a diallel or polycross

Figure 9. Seedlings of a non-tolerant population of *Agrostis tenuis* after six months of growth on copper contaminated soil (Walley *et al.*, 1974).

and progeny screened again for tolerance. The progress under selection can be considerable (Gartside and McNeilly, 1974).

There is no reason why this approach cannot also be used for adding another tolerance to tolerances already existing. Selection for tolerance to zinc in material already tolerant to copper has been shown to be effective (Walley *et al.*, 1974) (Table 2). In this way, plant material can be tailored to the requirements of the problem situation. This is being carried out in our laboratory. At first sight, this may seem a large amount of trouble for solving an individual problem. But areas of mining dereliction now being produced are often extremely large and the tolerant material, once it has been produced, can be used in substantial quantities. It is also likely that the material can be used on other similar sites in the same climatic zone, particularly if versatility such as tolerance to several different heavy metals can be incorporated into the same material.

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TABLE 2. The zinc and copper tolerance of surviving seedlings of various samples of *Agrostis tenuis* after screening for zinc tolerance (Walley *et al.*, 1974)

Population	Individual	Tolerance		Mean Tolerance	
		Zinc	Copper	Zinc	Copper
Normal population selected	1	28.6	0.9		
(survivors from various zinc waste/soil	2	41.3	0.0	31.8	0.3
mixtures)	3	25.6	0.0		
Copper mine population selected	1	47.8	49.9		
(survivors from various zinc waste/soil	2	30.8	66.9	36.4	52.1
mixtures)	3	30.7	43.5		
Pasture population	1	0.0	8.6		
(individuals from a pasture)	2	1.7	0.0	0.6	2.9
	3	0.0	0.0		
Copper mine population	1	20.2	76.1		
Unselected	2	16.2	93.5	17.6	85.3
(seed grown on normal soil)	3	17.2	86.5		
Copper mine population (individual from a mine)	1	0.8	87.5	0.8	87.5
Zinc mine population (individual from a mine)	1	93.0	3.8	9[illegible].0	3.8

l.s.d. (5% prob.) 7.1.

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DISCUSSION

G. A. Jung (Pennsylvania, USA). You indicated a greater uptake of calcium. Could you tell us whether that efficiency is also exhibited when you have more calcium in the soil?

Bradshaw. At the highest level of calcium, the two populations of *Festuca ovina* were similar but not in the work that Roy Snaydon did on *Trifolium repens*. He found that, both for calcium and for phosphorus, the populations which were tolerant of low levels of either had higher levels of calcium or phosphorus, as the case may be, throughout the whole of the range of treatments we gave, quite conspiciously so.

W. Smith (Texas, USA). I'm interested in the content of zinc and copper in the plant tissue.

Bradshaw. Well, that's an interesting point. Tolerance does not stop metals from getting into the plant. In copper tolerant plants, though, the metal seems to reside almost entirely in the root and you get very low levels in the upper parts of the plants.

It appears from the work that's been done that there is a complexing system that holds that copper in the plant in an innocuous form. For lead and zinc, it does appear in the tolerant plants that the metals move up into the tops of the plants, but the levels are lower in the tolerant material than they are in the non-tolerant material. Here are some values from a pot experiment for exactly the point that you raised involving populations of *Festuca* on lead/zinc waste. Without fertilizer the commercial non-tolerant population has 2 000 mg/kg in its upper parts, whereas the tolerant material has only 300 or 400. The same applies to zinc; commercial material has almost 4 000 mg/kg but the tolerant material has only 1 500. However, if you put on lots of fertilizer you actually equalize the uptakes. Animals can't eat this material as a substantial part of their diet. By this system you're not going to make grazing pastures out of metal wastes containing, say, 1% lead and zinc. But it's perfectly good for stabilization. I think we don't know enough about the range of variability at the moment. You see, *Lotus* is a very interesting example. As far as I can see the seed sources that we have in Britain are grown on calcareous soils and I don't believe that it's anything like the same species, particularly judging by what I said when you were giving your paper, as the material which is growing in other places on acid soils. I don't think when we look at *Lotus corniculatus*, as a case in point, we should consider it one thing by any means. It may be very confusing when you buy seed from a local supplier, because you just don't know where, unless you can identify it, it has been raised or what its past history is and so you may get some very confused results. One person may say that they get *Lotus corniculatus* to grow on an acid soil and another one, I suspect, will say he can't get it to grow. This would depend upon what material they got hold of. Certainly, if the species we've looked at are anything to go by, this could well be true. So it should be very interesting if anyone else has got any experience on this variability within legume species.

O. Bennett (West Virginia, USA). We've got a man in the audience, Dr. Charlie Foy, who has been doing a lot of work in this area and I'd like to hear his comments.

C. Foy (Beltsville, Maryland, USA). I was hesitating because we hadn't studied the nodulation question, which is of practical significance in the final analysis, but two or three pieces of work might be of interest to you. First, we started studying alfalfa varieties and I asked the plant breeders if we should consider them legumes. Without exception, they all said let's not complicate the picture; let's leave them as non-legumes and fertilize them with nitrogen. So we did that and we established significant differences between commercial varieties of alfalfa. Dupuits is better than Buffalo on a strongly acid soil. But we tried to repeat that on different batches of the same soil and we could not do it. We finally decided that one of the problems was the extreme variability from plant to plant within a variety. You will find within one pot of an acid soil plants that are from 2 inches to 8 inches high. Finally, Dr. Clarence Hanson and I went in and selected from the low lime levels (pH of about 4.5 to 4.9) individual plants representing strong and weak populations together and then polycrossed them with bees, intercrossed them within each group, and established two populations. Then, these two populations were subjected to Tatum and Bladen soils which are known to be aluminum toxic and recurrent selection was practiced to try and shift the population on a statistical basis from the sensitive end to the tolerant end. We have a paper published in this year's *Plant and Soil* on this.

Tom Devine is the senior author. He is the plant breeder that you might contact on this work. Also, Jim Elgin is carrying on this work. The evidence is that aluminum tolerance in alfalfa is genetically controlled and that you can, by recurrent selection techniques, shift the population a little bit, but we still have a long way to go—only a small percentage of the plants are tolerant.

There are another couple of points on this. I think another hope is some work that we've been doing with lupins. We have just done these studies in pot culture. But we find that the chemical factors are so dominant that we can find them in the greenhouse and be pretty sure they'll persist in the field. Aluminum toxicity dominates everything else so in the pot cultures we have found that white lupins, *Lupinus alba*, from several sources in the world are consistently more tolerant to an acid mine spoil at pH 4 than, let's say, *Lupinus luteum*, and several sources of seed indicate this. Of course, again, we fertilized this soil with nitrogen because we didn't do anything on inoculation. But under those conditions, we find that yellow lupins are always chlorotic on the acid soil of pH 4—that's on mine spoil. Furthermore, I found on the Cecil soil that I could induce the same type of chlorosis by adding excess manganese. It looks like it's an iron problem that's induced by an imbalance between iron and several metals on the mine spoil. And whatever it is, it is very consistent. The white lupins are superior. I understand in Australia they are grazing them, they are using them for seed, for feed and so on. Another thing, very recently I have been studying some tropical plants and the hyacinth bean is tremendously tolerant to an aluminum toxic Tatum soil of pH 4.2. It gave very little lime response at 4.2 where most legumes will die. The hyacinth bean is a tall thing that grows 10 feet high and can be

used for human food as well as for other purposes. But it has several different names which I understand are constantly being changed—hyacinth bean, Lablab purpurea, and there's still another.

D. Plucknett (Hawaii, USA). There are a number of tropical legumes which do, I think, fit a number of ecological situations that are very difficult. Dr. Bradshaw mentioned this and it is certainly true. We have known that *Stylosanthes* species were very tolerant of aluminum toxicity and this sort of problem. But there is a new, much broader collection of *Stylosanthes* being made by the SEAOT in Columbia by Burt Groff under sponsorship of the International Board for Plant Genetic Resources, and he's found some very interesting extremes of tolerance that we didn't have before. I would also mention that I second the idea of going to these tropical areas where there are some very difficult and unusual soils. High titanium soils exist in the tropics, there are plants that have adapted themselves or evolved there; there are very high aluminum soils of various kinds. There are many of these kinds of unusual soils which you would never think would be possible and I think we really should be exploiting these more than we have.

J. E. Winch (Canada). I would like to compliment Dr. Bradshaw on a fine piece of work. I think this is a good start. However, I do have some questions about practical use of this sort of thing. If we develop specific lines or ecotypes for specific situations, how is the commercial operator going to obtain seed of this specific kind or type in the quantity he needs to do the job? And the second point is that he has shown quite amply that there are tolerances within the grass species to lead, copper and so on. I just wonder if he has had any experiences with any of the legumes in this direction?

Bradshaw. These are two very interesting questions. As to supply, you're always going to have a problem with the supply of seed for a small local area. Various speakers talking about hill land and providing specialized adapted materials for it have raised this point. Dr. Breese, in particular, made this point and they were trying in Aberystwyth to get species that would do well in the lowlands and yet do well in the hills. Now, I think that is obviously the way one should try to go but when you get to these very specifically difficult sites I think one has got to be prepared to produce something special. I look at it in two ways—if a mining company has a large continuous profitable operation, it could afford to develop its own material doing all the sorts of things we did. When you can circumvent the trouble by picking up clonal material and using that by hand, really the operation is terribly cheap and simple and as you saw in the last slide I showed, it was being done. The project I described used only 1⅓ people working for three years to get that far, with a bit of time afterwards to produce the seed. The seed is now being produced, so it isn't impossible. We just got 2 cwt of Merlin back after three years of seed production. I think it is feasible though it's going to be more expensive than normal seed. I also think that it's important now that some of the mining operations are very big and they could therefore afford to do it.

The other question is actually more important. I was going to raise it myself. It occurs throughout the whole of this symposium that legumes are clearly very important things. They represent, particularly now with the price of nitrogen being what it is, a very sensible way into soil improvement problems and never is this more visible than on derelict lands produced by mining. You start with almost nil. With regard to metal tolerant legumes, we've never come across any in the temperate region but I wonder about *Lotus corniculatus*, because I once found this on a mine site and we haven't yet got around to looking at its tolerance. But I think there is a very fascinating area of investigation here, because if you look at the literature there is a whole series of legumes to be found associated with the accounts of metals in tropical and subtropical regions. The particular person who has shown this is Professor Mild, Botanist at the University of Rhodesia. Some of these old metal anomalies which have been in existence since the tertiary, have quite a range of legumes. Nobody else has ever shown that they are specifically tolerant but they are growing on these metal areas so I can only presume that they are. The next thing: are they any good—are they just growing, you might say, not as legumes as we think of it, just as plants? Do they get their nitrogen by other means or have they got tolerant rhizobia? I don't know. I think it's a very interesting area—it's got a very interesting academic challenge, and if you could get a legume that really was metal tolerant it would be very interesting.

But I would like to raise a more general point and it comes out of Mr. Barrows' talk. What about legumes for extreme acid soils? When you've got these pyrite problems they tend to be there even if you cover them up with a bit of topsoil. It would be nice to have legumes that would tolerate these extremely acid conditions. I'm very aware of the fact that sometimes when we're struggling to grow clover on acid, siliceous waste which was produced by China clay extraction in Cornwall, we're struggling to grow clover putting lime and phosphorus on and in our check plots we're pulling out *Ulex europeas* because it's getting in the way—growing perfectly well without any apparent assistance from anything. I don't really understand where it gets its nutrients. So, we have some species which are no good really—you can't use *Ulex europeas* (gorse)

as a grazing plant—but have we done enough on legumes, or in the United States has enough been done on legumes, for very acid conditions—either species or identifying populations within species?

H. L. Barrows (Washington, D.C., USA). Yes, we are working with legumes. In fact, George Griebel, who has been working on this, is here today. We have been screening our entire rhizobia collection in an effort to find those that can be grown successfully on these very acid conditions. We also are looking at steps that we can take to neutralize the toxic factors in the soil to give both legumes and rhizobia better opportunities for growth. We've had quite a bit of success in establishing various legumes. We have eight or ten that will grow very well—they do nodulate. I don't know whether we have any data at this time as to how well they fix nitrogen, but they may. We are able to get nodulation on some of these very adverse soil conditions.

G. Griebel (Beltsville, Maryland, USA). We have identified some species which are listed in the USDA publication *Revegetation of Land Disturbed by Strip Mining of Coal in Appalachia.* I'll mention them briefly, Kura clover and zigzag clover (*Trifolium ambiguum* and *T. medium*). But where do we get the seed to produce them? These are poor seed producers; some produce seed that is difficult to harvest. Birdsfoot trefoil (*Lotus corniculatus*) is recommended in western Maryland for strip mine revegetation. Ladino clover does well for a year or two but we don't know why it disappears. In southern West Virginia we have crops of alfalfa. Now, we've had to plant a weevil resistant variety but it's persisted for four or five years. Crownvetch does very well. We have sericea lespedeza, which is planted throughout West Virginia. So there are many that are now currently being used in the Appalachian area for this purpose. As far as selecting the acid-tolerant strains of rhizobia, I've had a little bit of difficulty because you can't do it on a solid medium. At the pHs we're working with, the agar does not gel. So, we've had to go to liquid cultures, and it is very difficult to find media, but they are persisting and they're obviously producing nitrogen. How much they produce or why, we still don't know. We're just getting started on this.

77.
Reclamation of Surface-Mined Areas in the United States

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Whether we are digging for earthworms with a hand trowel in our backyard or digging for coal with a mammoth machine that removes 168 cubic meters of earth with each bite, we have the same objective: we want to use the resource that is within the earth. If we are digging in our backyard, we will make certain that, after we have removed the earthworms, we fill in the hole and smooth the area so it can be used for lawn or garden. The same principle must apply when we are disturbing larger areas. Once the resource has been recovered, we must restore the areas to at least their premining level of productivity. Until recently, however, this has not been the practice in the United States.

We have vast areas of disturbed land in this country. The Soil Conservation Service (SCS) estimated that as of January 1, 1974, a total of 1.8 million ha had been disturbed by surface mining (USDA-SCS, 1974). Almost half of this mining was for coal, about one-quarter for sand and gravel, and the remainder primarily for stone, gold, phosphate, iron, uranium, and clay (Newport and Moyer, 1974). Over 1 million ha still need reclamation (USDA-SCS, 1974). Areas disturbed by mining increased by about 0.5 million ha over the past ten years (USDA-SCS, 1974). We are currently disturbing about 80 000 ha per year. By 1980, we will have disturbed 2.2 million ha (Newport and Moyer, 1974). It is conservatively estimated that more than one-third of the land area in the United States has the potential of being seriously disturbed by man at some time in the future. This would include mining for minerals and fossil fuels and disturbance by large construction projects. It is important, therefore, to develop the technology required to revegetate and reclaim large disturbed areas.

Inasmuch as coal mining is responsible for almost one-half of the disturbed mine land in the U.S., most of my remarks will be directed toward this activity. I will comment briefly on our coal reserves, then

review the growth of surface mining activity in this country, examine the environmental problems associated with mining and reclamation, review the research currently underway and identify future research needs. Many agencies are conducting research on strip mine reclamation; however, I will be placing particular emphasis on the research program of the Agricultural Research Service (ARS).

COAL RESERVES

For centuries man has recognized some of the advantages and disadvantages of coal. The Chinese are said to have used coal as long ago as 1000 B.C. The first documented evidence that coal was mined in Europe is in the chronicle of the monk, Reinier, about A.D. 1200. During the reign of Edward I (1239–1307), the death penalty was imposed on those found guilty of burning coal due to the noxious fumes emitted (*Encyc. Britannica*, 1963).

Coal deposits are located in most of the major countries of the world. Mainland China has vast deposits, as does the United States, the USSR, Belgium, France, West Germany, and the Netherlands. North and South Korea, North Vietnam, the United Kingdom and the Republic of South Africa also have large reserves. The total original world resources are estimated at 15.1 trillion MT. The identified world resources are 4.9 trillion MT, with the U.S. contribution to this being 1.6 trillion MT, or about 33% of the total world supply (Averiti, 1975).

Alaska and 36 of the 48 conterminous United States have coal deposits. The locations of the major coal deposits in the 48 conterminous States are presented in Fig. 1 (Averitt, 1975). Thirteen percent of the total land area in the United States is underlain by coal. Two states, Illinois and West Virginia, have coal deposits underlying over two-thirds of their land area, and thirteen states have deposits under 20 to 45% of their land area. Over 96% of the 17 billion MT of anthracite reserves are in Pennsylvania; most of the remainder is in Arkansas and Virginia (Averitt, 1975). Approximately 70% of the 1.6 trillion MT of bituminous coal and lignite reserves are west of the Mississippi River. However, based on caloric value, about 55% of the reserves are east of the Mississippi River, with the largest concentration of high-quality coal in the Appalachian Region (Averitt, 1975). Based on an estimated 60 to 64% recovery with present-day technology (Lourie, 1968), our estimated recoverable reserves are between 960 and 1024 billion MT. In 1973, we produced 542 million MT of coal (Averitt, 1975). Even with estimates of

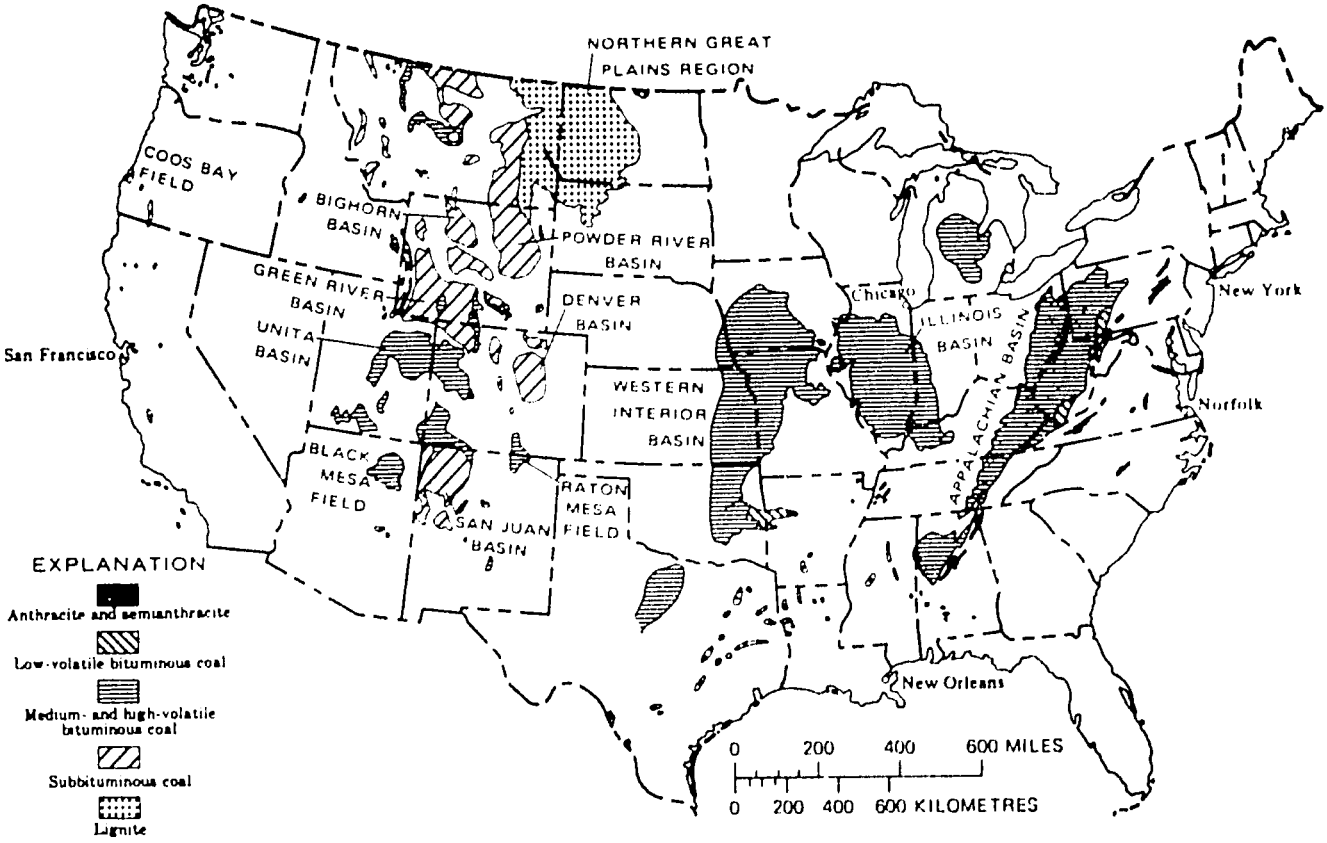

Figure 1. Coal fields of the conterminous United States.

1 billion tons annually by 1980 (Hunter, 1970), our known recoverable reserves will last us nearly 1 000 years. However, removal of the remaining recoverable coal could disturb almost 184 000 square km, an area larger than the states of Pennsylvania and West Virginia (Averitt, 1970).

GROWTH OF SURFACE MINING

Coal mining in the United States began in 1701, along the James River, near Richmond, Virginia, but coal was not mined commercially until 1745 (*Encyc. Britannica*, 1963). The first coal mining probably could be classified as surface mining. Coal was chipped out of the ledges discovered along river or streambanks. Some of the overburden was removed with pick and shovels, but with the tools available, it was not practical to remove more than a few meters of overburden. The early miners were then forced to tunnel into the coal seams to remove it. This set the pattern for coal mining in this country. Indeed, most of the hundreds of mines that went into operation between 1910 and 1945 were subterranean mines, tunneling for miles into the meandering ridges.

This picture changed, however, with the development of large earth-moving equipment. It was then possible to remove greater depths of overburden to reach the coal seam. In 1946, the average depth of overburden removed was 10 m, and the deepest cuts were only about 21 m. By 1970, the average depth of overburden removed was 17 m, and the deepest cuts were 56 m (Averitt, 1975). The amount of overburden that can be removed to reach the coal seam depends basically on economics. The operator can afford to remove more overburden to mine a high-grade coal than he can to mine an inferior coal. Also, if he can reduce the cost of earthmoving, he can afford to remove more overburden. In 1946, the ratio of the depth of overburden removed to the thickness of coal seam was 6:1. In other words, the operators removed 6 m of overburden to recover a 1-m vein of coal. In 1955, the ratio had increased to 8.5:1, and in 1970, it was 11:1 (Averitt, 1975). These are average figures, and it is quite obvious that many operators exceed them. For example, in 1965, the average ratio in Oklahoma was 29:1, and in parts of Illinois ratios larger than 30:1 are being used. Averitt (1975) suggests that, "within the lift and swing limits of existing machinery, the 30:1 ratio is technically feasible as a maximum for present and near-future strip mining."

The percentage of coal mined by surface mining is increasing. In 1917, strip mining accounted for only 1% of the total coal mined in this country. By 1968, this figure had risen to 34% (Averitt, 1970) and in 1973, it was almost 50% (Averitt, 1975). In 1965, only 4% of the total land area in the West had been disturbed by surface mining. Obviously, this pattern is changing. Forty-five percent of the nation's coal reserves lies in North and South Dakota, Montana, and Wyoming, and 23% of all reserves is in North Dakota (U.S. Department of the Interior, 1973). This coal is under terrain that is ideally suited for intensive surface mining by massive machines. Approximately 70% of our strip-mined coal is used to generate electricity (Averitt, 1975). Many large electricity-generating plants have been built adjacent to the Western coal fields. Some of the larger ones will consume nearly ten tons of coal a minute. As our energy requirements increase, coal production will increase. An estimated 1 billion MT of coal per year will be required for generating electricity by the year 2000 (Hunter, 1970). Lignite production in North Dakota alone is expected to increase from 5.7 million MT in 1972 to about 41 million MT by 1990 (Sandoval *et al.*, 1973). Almost 100% of the coal removed from North Dakota, Montana, Arkansas and the Southwestern U.S. is surface mined.

Due in part to our increased need for energy and in part to advantages of surface mining over underground mining, the percentage of coal removed by surface mining will continue to increase. The output per man-day is more than three times greater and operating costs are 35 to 40% lower with surface mining than with underground mining (U.S. Department of the Interior, 1973). Coal recovery also is much higher, often reaching 90% as compared with 50% from underground mining. Further, mining fatalities are five times greater in underground mining than in surface mining (Averitt, 1970).

ENVIRONMENTAL PROBLEMS ASSOCIATED WITH SURFACE MINING

Appalachian Region

Early surface mine operators in this country had no legal restrictions. Most often they did not own the land surface they mined, just the minerals beneath the surface. They were free to remove these minerals by whatever means necessary. They did just that and made no effort to reclaim, or even partially stabilize, the piles of material thrown aside during the mining operation. In the wake of the miners lay a ruined, denuded landscape that could not support vegetation; soils subject to accelerated erosion, rockslides, and landslides; streams clogged with sediment and acid; and impaired groundwater. Because of the harshness of these residues, many mined sites in the Appalachian Region still are without vegetative cover decades since they were disturbed. Branson (1974) estimates that more than 600 000 ha in Appalachia have been directly affected by mining.

In 1939, West Virginia enacted laws controlling surface mining. Indiana acted in 1941, Illinois in

1943, Pennsylvania in 1945, Ohio in 1947, Kentucky in 1954, and Maryland in 1955. Now over half of the states have laws regulating surface mining of coal and other minerals, and there are federal regulations governing strip mining on federally owned land in the West. The early laws, while placing certain restrictions on the operators, generally did not offer adequate guidelines for methods to stabilize the disturbed areas. The technology was not available.

In the Appalachian Region, coal is mined in very rugged terrain—steep mountains bisected by narrow valleys. Coal seams are almost horizontal. In the early days of mining, the seams were exposed by scraping off the overburden and pushing it down the mountain slope. The final result was an almost level bench, following the contour around the mountains, with an exposed high wall and a steep outerslope consisting of highly erodible overburden. The SCS estimates there are approximately 5 800 km of unstable outer slopes (USDA-SCS, 1973). The key to stabilizing this material is to restore the vegetative cover, but the material is not conducive to natural revegetation. The spoil materials are highly variable, consisting of soil, subsoil, and unweathered rock. They are practically devoid of organic matter and plant nutrients. The very low water-holding capacity, 3 to 5% (Jones *et al.*, 1975b), and the highly dispersed clays result in a surface environment that is often dry and covered with a thin crust almost impermeable to water. Furthermore, the pyritic rock associated with the coal seams oxidizes when exposed to air. It then reacts with water forming sulfuric acid, which further contributes to an inhospitable environment for plant growth. Many spoils in Appalachia have a pH as low as 2.5. Few plants will survive at this pH. Also, the acidity causes other minerals to become available in amounts toxic to plants. Toxic levels of Al, Mn (Berg and Vogel, 1968, 1973), Cu, Ni, and Zn (Massey, 1972; Massey and Barnhisel, 1972) have been reported in acidic spoil material.

The acidity in the spoil material is not only detrimental to plant growth, but is leached or carried by runoff water to streams and rivers where it causes serious problems for fish and other aquatic life. Acid drainage, 12% of which comes from surface mining, has seriously polluted over 9 000 km and altered almost 17 000 km of streams in Appalachia (Appalachian Regional Commission, 1969). In 1970, it was estimated that leaching and erosion of mine spoil banks contributed more than 1.8 million MT of sulfuric acid to streams annually (Averitt, 1970). Vimmerstedt (1970) reported greater sulfate, Mn, Fe, and Al concentrations in Ohio streams draining strip-mined areas than from non-mined areas. Concentrations often exceeded those acceptable in water for domestic use. Davis (1973) reported 18 mg/l Mn and 990 mg/l sulfates in the Tradewater River, which drains mined areas in Kentucky. He also reported sulfate concentrations of up to 1 260 mg/l in a watershed disturbed by mining, as compared with only 50 mg/l *total* dissolved minerals in an undisturbed watershed.

Without adequate vegetative cover, much of the precipitation falling on the disturbed area immediately runs off the surface. Peak flows are three to five times greater from mined areas than from undisturbed areas (Curtis, 1972). This results in severe erosion as well as failure of the outer slopes. It is estimated that over 60% of the stripped land in Appalachia is eroded or subject to erosion. Forty percent of the stripped land in Appalachia is eroded enough to form rills and small gullies, and 12% enough to form gullies more than 30 cm deep (USDA-SCS, 1973). Based on a survey conducted in Kentucky, an estimated 12% of the outerslope area had failed, carrying large masses of spoil downslope and into stream channels (Curtis, 1973). Curtis (1971), reported sediment loads of up to 46 000 mg/l from instrumented watersheds in Kentucky. Compare this with 150 mg/l in runoff from adjacent undisturbed watersheds. In another Kentucky study (Branson, 1974), the concentration of sediment delivered to a stream from a mined area was 112 000 mg/l as compared with 100 mg/l in unaffected streams. Nephew (1973) reported that erosion from freshly stripped areas in Appalachia may be 1 000 times greater than that from undisturbed areas. Branson (1974) reported that strip mining in Kentucky increased siltation in streams by as much as 15- to 30-fold and observed sediment loads of 899 kg/ha from mined sites and 5 400 MT/km from haul roads. Branson (1974) estimated that clogging of stream channels by sediment has reduced the carrying capacity of more than 60% of the headwater streams in Appalachia by two-thirds or more, increasing the risk of flooding.

Western Region

In the West, coal is surface mined by using a large dragline to dig a trench through the overburden to expose the coal seams. After the coal is removed, a second trench is dug adjacent to the first, and the overburden is deposited in the first trench. Until laws were passed that required regrading and covering the spoil with topsoil, the topsoil was buried in the bottom of the trench and the material immediately above the coal seam was left on the surface. The final appearance of a mined area was a series of roughly parallel ridges and valleys, with infertile spoil material on the surface.

While acidity is not a problem in western coal fields, other problems are just as severe. The spoils are low in P and organic matter and often contain large amounts of Na, B, and Mg. Freshly exposed

spoil material may contain adequate N for plant growth, but this disappears after about two years. Power *et al.* (1974a) reported up to 500 mg total N/kg in the shales above the coal seam in North Dakota. Freshly weathered shale contained approximately 20 mg NO_3 N/kg, but after exposure for two years, the N disappeared. Much of the exposed spoil material is very fine textured. Spoils from the Tongue River and Sentinel Butte formations within the Fort Union group in North Dakota contained over 50% clay-size fractions (Sandoval *et al.*, 1973). This was predominantly montmorillonite, moderately saline and highly sodic. Salinity increased in severity with depth from the original surface. The low organic matter, high clay, and high absorbed Na contents render the spoil materials extremely unstable, subject to massive piping, or irregular subsidence, and highly impermeable to water. Sandoval *et al.* (1973) flooded a 6 cm column of spoil; after four days, no water had moved through the column. In subsequent studies, no water moved through an 8.2 cm column of spoil even after 127 days in which a layer of water was maintained on the surface (Doering and Willis, 1975). Such a soil will support very little vegetative growth and is highly susceptible to wind and water erosion.

While surface mining disturbs the natural vegetative cover, we have developed the technology to restore cover in most areas of the country. However, revegetation is not likely to succeed in areas having less than 250 mm annual precipitation unless irrigation is available. Unfortunately, this situation prevails in many parts of the western coal fields where annual precipitation ranges from about 100 to 500 mm. An example is the San Juan Basin in northern New Mexico, which has an annual rainfall of 150 to 200 mm. Without irrigation, revegetation attempts will be successful in only one year out of ten (Aldon, 1975b).

While revegetation attempts in low rainfall areas present problems, they are not nearly so great as the problems created by the effect of surface mining on the hydrology of an area. This is particularly significant in the western coal fields where activities such as ranching depend on a barely adequate supply of water, and any decrease in that supply can be critical. In many western coal fields, coal seams near the surface are also groundwater aquifers serving livestock and domestic wells. Mining operations that cut into these may reduce or eliminate the flow to distant wells. Mining operations that deplete the water table cause many problems. As the water table drops, natural protective vegetation in some areas may die, thus exposing the land to more extensive erosion. Similarly, stripping operations that destroy the surface drainage features of a mining site may have serious hydrologic repercussions on the surrounding unmined area. Eradication of old drainage channels forces the runoff from infrequent, but intense, storms to cut new channels, thus increasing the erosion. Furthermore, drainage water from mine spoils is a source of water pollution. In addition to sediment, the water carries higher loads of Ca, Mg, Na and sulfates that are reflected in the lowered quality of the streams draining the area (McWhorter *et al.*, 1974). Despite all of this, little research has been done on the hydrologic impacts of surface mining.

Oil Shale

With our limited petroleum supply, we can expect oil shale mining to become a greater contributor to disturbed land. About 30 states have oil shale deposits, but the most important deposits are in the Green River formation, covering about 42 735 sq km in Colorado, Utah, and Wyoming (Pfeffer, 1974). Roughly 75% is contained in the 4 144 sq km Piceance Creek Basin of Colorado. The deposits are about 610 m thick and assay at about 86 liters/MT (Burdick, 1974). Both deep mining and surface mining will be used to recover the shale.

Not only are there problems in reclaiming the mine spoil material, but the spent shale must be disposed of and the site reclaimed. The spent shale volume is roughly 20% greater than that of the raw shale in place (Pfeffer, 1974). The characteristics of the spent shale depend on the processing method. In the TOSCO process, the shale is finely divided—90% is silt size or smaller, highly saline, black, and devoid of most plant nutrients. In this form, it will not support vegetative growth and is subject to wind and water erosion. Furthermore, water leaching through the material carries with it high concentrations of dissolved salts that can contaminate surface or groundwater. We have no satisfactory method for disposing of the spent shale. The magnitude of the problem can be visualized when one considers that in one year the spent shale from one 50 000-barrel-per-day plant would cover a 32 ha area to a depth of 30 m. There are an estimated 600 billion barrels of oil in the three-state area (Dinneen and Cook, 1974). Water may prove to be the limiting factor in the oil shale industry. With present technology, it takes about three barrels of water to produce one barrel of oil from oil shale.

Socio-Economic

Coal development also will have socio-economic impacts. Substantial resources now used for agricultural production will be shifted to coal development. Land disturbed for mining may be returned to other uses. Some land that may be used for transportation, industrial, and residential purposes probably will be irreversibly lost to agricultural production. The impact of water diverted to coal processing and transportation uses will be felt not only locally but

downstream. Rural communities also will be affected. Coal development will result in new employment and population increases. Existing towns will grow and new towns will develop. These communities will be burdened with providing a variety of services such as transportation, schools, medical facilities, homes, and sewers. A fundamental problem will be financing the additional services demanded. These impacts must be assessed and considered in the total environmental impact of coal mining.

RESEARCH ON RECLAMATION OF DISTURBED AREAS

Following the Open Cast Act of 1958, Britain developed high standards and techniques for successfully reclaiming surface-mined areas (Doubleday, 1974). Technology was also developed for highly successful reclamation in Germany. Due to the difference in climate and characteristics of the spoil material in this country, as compared with those in Europe, the technology could not be transferred directly. Research was needed to develop the technology required to revegetate and reclaim areas under the harsh environment left by strip mining in this country. Unfortunately, practically no reclamation research had been conducted in this country prior to 1965, and only a limited amount was conducted prior to 1970. This has changed. The Smithsonian Science Information Exchange now lists more than 125 projects related to strip mine reclamation.

The U.S. Department of Agriculture was called on to develop technology to revegetate the surface-mined areas. Since most of the mined land east of the Mississippi River was originally forested, the U.S. Forest Service began research to develop methods for reforestation. The Agricultural Research Service (ARS) began research on revegetation of strip-mined land in 1966. These were exploratory greenhouse studies that provided background information for field experiments started in 1970 in West Virginia and North Dakota. Research is now underway by several agencies, departments, and states.

To coordinate and manage the various reclamation research programs within the USDA, the Department established the *USDA Program for Reclamation of Lands Affected by Mining (RECLAM)* (Secretary's Memorandum No. 1898, June 1, 1976). The RECLAM program is designed to "provide leadership, technology, and assistance in (1) protecting land and related resources; (2) maintaining and developing agricultural production systems; (3) helping rural people, communities and people in other economic systems deal with problems, needs and opportunities affected by mining and related activities; and (4) identifying critical land areas that should not be disturbed." The ultimate goal of the program is to assure that the nation's energy and mineral needs are met in a reasoned, selective, and orderly way, without sacrificing food and fiber, quality of living in rural areas, or quality of the environment. The program is implemented by a coordinating committee comprised of the Assistant Secretary for Conservation, Research and Education, and the administrators of those agencies with responsibilities for land reclamation. A Research and Development Work Group, comprised of representatives from the ARS, Cooperative State Research Service (CSRS), Economic Research Service (ERS), Forest Service (FS), and Soil Conservation Service (SCS) has responsibilities for proposing a coordinated research and development program to the coordinating committee. Furthermore, the program provides a mechanism for close-working relationships and coordination of the USDA program with other federal departments and non-federal agencies that have major responsibilities for mineral management and environmental research and regulations. This insures that the USDA activities are integrated into the overall national program of energy and mineral development.

Each agency represented on the Research and Development Work Group has developed a research plan describing its contribution to the total USDA program. The ARS National Research Program (NRP) is entitled *Reclamation and Revegetation of Land Areas Disturbed by Man* (ARS-NRP-20770). The objectives of this program are to develop technology and methodology to:

1. Integrate reclamation and land use plans into total mining plans prior to mining.
2. Restore disturbed areas to optimum level of agricultural productivity or other use.
3. Stabilize disturbed areas against erosion, subsidence, and slides.
4. Prevent water degradation in and adjacent to disturbed land areas.
5. Utilize waste materials in reclaiming disturbed areas.
6. Improve scenic, wildlife, and aesthetic values of disturbed areas.

Research under this NRP is currently being conducted at ARS locations in Fort Collins, Colorado; Peoria, Illinois; Beltsville, Maryland; Ithaca, New York; Mandan, North Dakota; Coshocton, Ohio; University Park, Pennsylvania; Blacksburg, Virginia; Morgantown, West Virginia; and Cheyenne, Wyoming. Results from these relatively new research programs are already being used to revegetate and reclaim drastically disturbed land areas. This is particularly useful in the work SCS is doing in the Appalachian Region.

Almost 34%, or 607 000 ha, of the total land disturbed by all surface mining activities in the U.S. is in the five-state area of Kentucky, Ohio, Pennsylvania, Tennessee, and West Virginia (USDA-SCS,

1974). Over 334 000 ha of this area have been reclaimed; however, thousands of ha still need reclamation but are not covered by laws requiring it. These are the so-called "orphaned" lands that were mined before adequate laws were passed to control surface mining. The SCS, in cooperation with local conservation districts, is now reclaiming these lands. As of January, 1974, over 187 000 ha had been reclaimed in the five-state area (USDA-SCS, 1974). Without the results of research this would not have been possible. And, 121 000 ha of orphaned land still need reclamation.

The early goals of revegetation in the eastern United States were reforestation. The FS identified several species of trees that were tolerant to the harsh environment. The success of the plantings depended on the nature of the spoil material and the climate. It was not unusual, in the more adverse areas, to lose an entire planting. Even in those areas where trees were able to survive, they offered very little protection against erosion during the first few years. Studies were then initiated to develop a quick vegetative ground cover to protect the soil surface until the trees could provide a protective canopy. Vogel (1973) reported on a study in which cottonwood, sycamore, and Virginia and loblolly pine were grown either alone, with grass, or with grass plus a legume. After three growing seasons, the vegetation had produced 95% ground cover, but had reduced the rate of the tree growth. In the fourth and fifth years, growth of trees in plots dominated by legumes exceeded growth in plots with grass only or without herbaceous competition. Furthermore, the vegetative cover offered more protection against erosion than did the trees alone.

The ARS research program has stressed the need for a rapid vegetative ground cover. Grasses and small grains fit this requirement. Revegetation is not too difficult in some areas, but other areas offer extremely hostile environments for germination and seedling growth. Before any intelligent attempt can be made to revegetate these latter areas, the chemical and physical characteristics of the spoil must be identified. These must include potentially toxic elements as well as essential elements. Thus, the primary emphasis of the initial ARS research effort was to identify those characteristics adversely affecting plant growth and to develop methods for overcoming them so that vegetative cover could be established quickly on the spoil area. This research was conducted in cooperation with other federal and state agencies in both the Appalachian Region and in the lignite fields of North Dakota.

Appalachian Region

The extreme acidity in many spoils in the East was probably the primary reason, either directly or indirectly, for problems in revegetation. Many plants cannot tolerate acidity. Furthermore, the high acidity released toxic amounts of other elements present in the spoils, thereby damaging even those plants that could tolerate acidity. The approaches were (a) to select plants that were most tolerant to the spoil conditions, and (b) to alter the spoils to render them less harsh for plant growth. Both approaches were studied simultaneously.

Grasses that have shown promise on low pH strip-mine areas include bermudagrass, weeping lovegrass, tall fescue, big and little bluestem, Indiangrass, switchgrass, redtop, deer tongue, and bentgrass (Bennett *et al.*, 1972). Bermudagrass has proved to be particularly good in the Appalachian Region. When managed properly, it spreads quickly, produces large amounts of good forage, stabilizes the soil, and provides an insulating protective cover over winter that reduces freezing and thawing. It does require ample fertilization, however. Legumes that grow well on the acid strip mine area are birdsfoot trefoil, crownvetch, ladino clover, red and yellow clovers, hairy vetch, crimson clover, Kobe lespedeza, and Flat pea. Legumes are particularly important in strip mine reclamation because they can utilize atmospheric nitrogen. However, nodulation is poor on the acid spoils. Bennett (1973) has summarized the adaptability of a number of species to spoil and climatic conditions in Appalachia.

Soil amendments that have been used to overcome the toxic, acidic, and infertile conditions of strip-mine spoils are normal balanced fertilizers, lime, dolomite, superphosphate, and rock phosphate. Raw rock phosphate has been particularly beneficial. It contains approximately 30% P_2O_5 and 50% CaO, but in forms not readily available to plants. However, when applied to spoil material, its reaction with the sulfuric acid in the spoils neutralizes the excess acid and converts the P and Ca to forms that can be used by plants. While rock phosphate does not raise the soil pH appreciably, it does reduce the toxicity from Mn and Al. Bennett *et al.* (1972) applied rock phosphate at rates of 4 200 and 8 400 kg/ha to a spoil having an initial pH of 3.2. They then grew Tufcote or Midland bermudagrass in these plots. The soil pH was raised only to 4.0 by the rock phosphate, but the toxic effect of Mn and Al was reduced. The high rate of rock phosphate increased yield of oven-dry forage from 0.6 to 9.6 MT/ha for Midland and from 3.6 to 11 MT/ha for Tufcote.

Not all plants are as tolerant as bermudagrass to low pH. For such plants, lime must be added. At higher pH levels, the availability of P from rock phosphate decreases. Therefore, a suitable source of P in a balanced fertilizer is recommended. West Virginia now requires a minimum of 560 kg of 10-20-10 fertilizer/ha on all reclamation sites.

Some of the earliest attempts to revegetate strip-

mined areas demonstrated the advantage of surface mulches for seed germination and survival (Bennett, 1971). The mulch retains the surface moisture that is so essential and retards crust formation on the surface of the seedbed. Furthermore, a surface mulch offers some protection against erosion until the vegetative cover is established. The effectiveness of mulches to control erosion depends on many factors — erodibility index, slope length, slope steepness, and rainfall intensity. Since these are all variables in strip-mined areas, no single estimate of the amount and type of mulch needed to control erosion can be made. Meyer and Romkens (1976) reported that for short-length slopes with 3 to 5% grade on moderately erodible soils, 1 to 2 MT/ha of straw prevented serious erosion. However, over 4 MT/ha were required to control erosion on 15% slopes, and this rate did not adequately control erosion on a very erodible soil with 20% slope.

Although mulch is effective, it is expensive and is not always available in the quantities needed at a given site. Jones *et al.* (1975a) devised a system to obtain a quick ground cover which was then used as an *in situ* mulch to establish more persistent herbage of a quality acceptable for pasturage or hay. In the fall, Abruzzi rye or Blueboy wheat was drill seeded into a spoil having a pH of 3.8 to 4.0. This was fertilized with 67 kg N, 29 kg P, and 56 kg K/ha. In the spring, the wheat and rye, which had made good growth, were killed using Paraquat at a rate of 0.56 kg/ha. Barley was also studied, but it did not survive in the acid spoil. An additional 56 kg N, 118 kg P, 140 kg K, and 3.6 MT/ha dolomitic limestone were applied before planting grasses and legumes in the sod. With this technique, the grasses and legumes made excellent growth, with yields of 4 400 kg dry matter/ha. Highest yield in the third year was 6 000 kg of crownvetch/ha. This technique offers a method for establishing a quick vegetative cover on acid spoil material and providing an *in situ* mulch that promotes germination and stand of a more desirable species. Furthermore, the *in situ* mulch is only one-third to one-eighth as expensive as mulching material applied at seeding.

The steep outer slopes are among the most difficult sites to revegetate. One must contend not only with the adverse physical and chemical condition of the spoil, but also with the steepness and length of the slopes. Many slopes are at the angle of repose. Seed, fertilizer, and even mulches are washed down the slope by relatively low-intensity rainfall. Jones *et al.* (1973) developed a system for overcoming these difficulties. They cut a series of horizontal stairstep terraces, or grooves, about 35 to 60 cm apart down the face of the slope. The soil amendments, seed, and mulches were placed on the steps where moisture conditions were better. As a result, excellent germination of weeping lovegrass, birdsfoot trefoil, and crownvetch was obtained. After 90 days, they had an 80% ground cover on 65° slopes. Forage yields from the slopes exceeded 6 000 kg/ha after one growing season. The stairstep technique has also been used successfully in establishing bermudagrass on the steep slopes.

Forages, in addition to providing a quick ground cover with an economical crop, aid in restoring the spoil material to productivity. Jones *et al.* (1975b) established several varieties of grass and legumes on a spoil having an initial pH of 3.8 to 4.0. The initial organic matter in the spoil material was 0.2%. After four years, the pH in the top 22 cm of soil ranged from 4.7 to 5.7, and the organic matter had increased to 1.3%. Organic matter in the top 7 cm under orchardgrass exceeded 2%, and the water-holding capacity of the soil had increased from about 3 to 14%. This site is rapidly being converted from a barren, useless site to one that can be utilized for economic crop production.

More than 50% of the land in Appalachia now being disturbed by surface mining probably will be used as pasture or for other economic agricultural production. Yields of up to 11 MT bermudagrass, 4.5 MT clover, and 9 MT alfalfa forage/ha have been obtained from research plots. Specialty crops are also being evaluated. Tomato yields of 45 MT/ha and sweet corn yields of 8 000 ears/ha have been harvested. Studies are underway on the potential of strip-mine spoils to produce buckwheat, crambe, grapes, apples, and peaches.

Western Region

Attempts to revegetate the highly sodic spoils, such as those found overlying some of the deeper coal seams in the West, have generally been unsuccessful. Core samples have shown an increase in the sodium absorption ratio (SAR) as a function of depth. The SAR is an empirical relationship for expressing the effect of sodium on spoil properties. SAR values greater than about 12 indicate that spoils likely are dispersed and have physical properties adverse to plant growth. Values of over 60 have been measured in overburden at depths of 60 to 90 m (Sandoval *et al.*, 1973). If this material, which generally is high in clay and low in organic matter, is left on the surface, the spoil surface seals, thereby severely restricting water entry, aeration, and subsequent plant growth. Wali and Sandoval (1975) reported on one strip-mine site over 50 years old that still had only a very sparse native vegetative cover. The high Na, combined with high clay and low organic matter contents, results in a highly dispersed system that is almost impermeable to water infiltration (Sandoval *et al.*, 1973; Doering and Willis, 1975). In one study, 90% of the precipitation was lost as runoff from sodic spoils, even after rototilling (Power *et al.*, 1974b). Before these spoils can support

plant growth, they must either be improved through chemical amendments or covered with more suitable spoil material. Both approaches are being investigated.

Gypsum has long been used to improve sodic soils; the Ca replaces Na in the clay complex, giving a more stable soil structure and a more suitable environment for plant growth. In 1970, field studies were initiated near Mandan, North Dakota, in which surface applications of gypsum (22 MT/ha), straw mulch, topsoil (5 cm), topsoil plus straw, and topsoil plus gypsum were compared with a check. Both barley and adapted native grasses were planted in the test plots (Sandoval *et al.*, 1973). Gypsum improved infiltration slightly and reduced the SAR from an initial 23 to 14. Even with this 40% reduction, however, the SAR would likely restrict plant growth. After four years, the SAR in the top 15 cm was about 65% of its original level (USDA-ARS, 1975) but appeared to be approaching equilibrium. Thus, although gypsum will reduce the exchangeable sodium in sodic soils, it is very slow and may not eliminate the problem in highly sodic materials.

For gypsum to be effective, water must be able to percolate through the spoil to leach the displaced sodium below the root zone. However, Doering and Willis (1975) demonstrated that even a saturated gypsum solution (0.03N) did not maintain a suitable hydraulic conductivity for reclamation to proceed at a practical rate. Leaching with calcium chloride solutions of greater than 0.5 N would maintain adequate hydraulic conductivity for reclamation within a matter of days. Unfortunately, up to 27 MT of calcium chloride and over 500 cu m of water would be required to reclaim 0.4 ha to a depth of 30 cm. Obviously, the cost for large-scale leaching of sodic strip-mine spoils would be prohibitive.

A better reclamation method is to cover the sodic material with suitable topsoil. In the 1970 field studies at Mandan vegetative growth was much better on plots with added topsoil than on any of the other treatments (Sandoval *et al.*, 1973). Phosphorus deficiency was identified and corrected during the first year, and all plots receiving 5 cm of topsoil produced excellent stands of grass. By 1974, plots that had received no topsoil produced essentially no perennial grass, whereas the topsoil plots had a fair stand of desirable cool-season grasses (USDA-ARS, 1975). Additional studies showed that growth improved as depth of topsoil increased. Yields on plots receiving 30 cm of topsoil were over 1 800 kg/ha for native grasses and 4 500 kg/ha for crested wheatgrass (USDA-ARS, 1975). This work demonstrated the need for covering the sodic material with topsoil, but we do not know the depth that is required for adequate reclamation. Work is now underway to answer this question. In one study, sodic spoils are being covered with nonsodic subsoil in a gradually increasing depth from 0 to 2.25 m. This is then covered with topsoil at uniform depths of either 0, 20, or 60 cm. Spring wheat, alfalfa, wheatgrass, and native grasses are being evaluated on these plots.

Through the use of topsoil cover and adequate fertilizer, cool-season grasses, including western, crested, and slender wheatgrasses, and green needlegrass, have been established successfully on sodic spoils. However, little success has been achieved in establishing and maintaining warm-season grasses or other species suitable for midsummer grazing.

In the more arid sections of the country, such as that in New Mexico where the annual rainfall is only 150 to 200 mm, supplemental irrigation is essential for revegetating disturbed land. Aldon (1975a) has established alkali sacaton by planting only when soil moisture is 1 bar or less, soil temperature is about 30° C, and the probability of rain is highest. He irrigates thoroughly before planting, protects the soil with about 13 cm of mulch, and irrigates again within five days if it does not rain.

Use of Waste Material

The initial concern in reclamation is to establish a quick vegetative ground cover. This may have to be a species that has little economic importance; however, it may improve the spoil sufficiently to support a more desirable species. If this crop is to be used for animal or human consumption, we must be concerned not only with yields but also with nutritional quality. We must strive to maintain the proper ionic balance within the plant, but we must be acutely aware of the possibility of toxic concentrations of specific elements. This is particularly important when waste materials such as fly ash, garbage, or sewage sludge are used in reclamation. Studies are being conducted on the use of such waste materials in strip-mine reclamation.

Nearly 30 million MT of fly ash are produced annually (Adams *et al.*, 1972). Much of this is generated by coal-burning power plants often located near coal mines. Since this material results from burning coal, it is logical to return it to the mined area for disposal. However, this must be done in an environmentally safe manner and must not be detrimental to the reclamation process. For example, lignite fly ash is not acceptable for use in reclaiming sodic spoils. In North Dakota studies, not only did it fail to reduce the SAR, but it increased the pH to high levels, resulting in toxicities (Sandoval *et al.*, 1973). Fly ash varies widely in both macro- and micronutrient ranges from strongly acidic to highly alkaline. It also contains concentrations of B, Al, Cu, Mo, Fe, and Mn that may be toxic to plant growth if large amounts of fly ash are applied (Armiger *et al.*, 1976). Total analysis of fly ash cannot be used as the sole guide as to the acceptability of

a given fly ash. The elements Be, C, Ca, Cr, K, Li, Mn, Na, P, Pb, S, Tl, V, and Zn are preferentially concentrated on the surface of the fly ash particles (Linton *et al.*, 1976). The environmentally effective concentrations of these elements are thus much higher than those indicated from conventional bulk analyses.

Adams *et al.* (1972) applied up to 1760 MT of fly ash/ha as a 20 cm surface mulch to strip-mine spoil. Hay yields from these plots were about 9 MT/ha, but the forage contained up to 103 mg/kg B, 25 mg/kg Zn, 13 mg/kg Cu, and 4.3 mg/kg Mo. Plass and Capp (1974) raised the pH of spoil from 3.6 to 6.4 and increased the moisture-holding capacity with 330 MT/ha fly ash. Armiger *et al.* (1976) studied the effect of fly ash and rock phosphate on tall fescue and birdsfoot trefoil on a spoil with a pH of 3.2. Rates were 0, 5.6, and 112 MT of fly ash/ha and 0, 4.5, 9.0, and 13.5 MT of rock phosphate/ha. Fly ash incorporated into the spoil significantly reduced yields of birdsfoot trefoil as compared with surface applications. Boron toxicity produced by the high fly ash rate reduced yields of birdsfoot trefoil. Furthermore, fly ash alone increased plant content of B, Ca, Mg, Mn, Pb, and Cd. Both species, but especially birdsfoot trefoil, were high in Zn (up to 177 mg/kg). Both species also contained higher-than-normal concentrations of Pb (34 mg/kg) and Ni (88 mg/kg).

Fly ash can be used successfully in strip-mine reclamation if it is not applied in excessive amounts. Extreme caution should be exercised when it is applied to the surface and not incorporated into the spoil. Because fly ash is very finely divided, on the order of 20 microns in diameter (Adams *et al.*, 1972), it is highly susceptible to both wind and water erosion if left on the surface.

Approximately 45 million MT of sewage sludge are produced annually in this country. Sludge contains beneficial plant nutrients as well as some elements that may potentially be toxic. For years, sewage sludge has been applied to the land in Europe. Until recently, however, sewage sludge was incinerated, buried, or dumped into the ocean in this country. We are now studying the use of sludge and composted sludge as soil amendments. Included is research on the use of this material in strip-mine reclamation.

Like fly ash, sewage sludge varies widely in composition. Chaney (1973) reported *upper* limits of metals found in digested sludge as follows: 50 000 mg/kg Zn; 17 000 mg/kg Cu; 8 000 mg/kg Ni; 2 000 mg/kg Cd; 10 000 mg/kg Pb; 10 000 mg/kg B; and 10 mg/kg Hg. We must be concerned with these elements because they may be present in levels that would be toxic to plants or to the animal that eats the plants.

Results of using sewage sludge in strip-mine reclamation have been encouraging. In Ohio, Sutton and Vimmerstedt (1973) produced more than 4 200 kg of vegetative growth/ha on a strip-mined area treated with 650 MT of sewage sludge/ha. Control plots had no growth. An application of 55 MT/ha to spoils in Illinois increased corn yields fourfold and protein content by 2.5 percentage units over the control (Garcia *et al.*, 1974). Zinc, Mn, Cu, Pb, Cr, Cd, and Hg in grain, cobs, and husks were essentially the same in plants grown on treated and untreated plots. Rates of 90 MT/ha applied to West Virginia mine spoils resulted in a tall fescue yield of approximately 10 MT/ha, a tenfold increase over that from conventionally fertilized plots (Bennett, 1975; Bennett *et al.*, 1976). Zinc concentration in the forage on the sludge plots was increased to 30 mg/kg and Cd concentration was increased to 1.4 mg/kg. Chromium was not affected and B was reduced. Sludge had no overall effect on the Pb content, but despite treatment, forage samples collected in March contained significantly more Pb and Cu than samples collected in July. For example, Cu ranged from 4 to 6 mg/kg in the summer and up to 10 to 12 mg/kg in the winter. Lead ranged from 2 to 3 mg/kg in the summer but from 30 to 50 mg/kg in the winter. Forage containing these higher levels should not be fed to animals. Vole feeding trials were conducted in which 40% of the ration consisted of the forage from the plots. Kidneys of those fed summer-harvested forages contained 4.5 mg/kg Pb. This jumped to 9.0 mg/kg when they were fed the winter-harvested forage. The liver burden of Pb increased from 1.9 for summer forage to 4.0 mg/kg for winter forage (Haye *et al.*, 1975). Research is continuing to evaluate the potential use as well as possible problems resulting from the use of waste materials in the reclamation of strip-mined lands.

Hydrology

The paucity of information on the effect strip mining has on the hydrology and water quality of an area is recognized. Research is now being expanded on this. During the past year, ARS has initiated projects in Colorado, Ohio, and Pennsylvania. These, along with efforts of other government agencies and state institutions, will be providing much-needed information on this important aspect of surface mining.

FUTURE RESEARCH NEEDS

Reclamation plans, including proposed land use, must be developed before mining operations begin. To do this, more research is needed to identify all of the relevant chemical and physical properties of overburden material before mining begins and to relate these to soil amendments, plant species, and

management practices best suited for the area. The ultimate target will be to develop a computerized systems approach to reclamation that will be applicable over a broad range of soils and climates.

More satisfactory methods are needed to stabilize surface materials in the regraded areas. Water and wind erosion continue to be severe problems. To significantly reduce runoff and erosion resulting from mining activities, we need to improve landforming techniques to retard water flow and establish and maintain vegetative cover on disturbed areas. Small watersheds should be established in selected areas to evaluate the various erosion control practices. Slumping and sliding continue to be major concerns in regraded areas.

Many of the areas now underlain by coal have very low productivity. With proper regrading and management, some of these could produce more vegetative growth after mining than before. To assess this, we need continuing research on developing reclamation plans that will provide optimum land use of the area; regrading techniques designed for specific spoil, climate and intended use; selecting and breeding plant species of economic importance for specific areas; and evaluating sources, rates and placement of fertilizers, and other soil amendments to optimize growth and quality of plants. Ultimately, the results of this work will enable us to recommend the best land use and the best combination of management practices required to reclaim completely the distrubed areas.

Vast quantities of solid waste and sewage sludge are produced annually in this country. This material could be used in reclaiming disturbed areas. However, more research is needed to evaluate the effects of waste materials on the chemical status of spoil material and vegetative growth; to determine the effects of various rates and compositions of waste materials on water infiltration, runoff, and quality; and to devise corrective measures to overcome any detrimental effects waste materials may have on the growth and nutritional quality of plants. The ultimate goal of this research is to develop recommendations for safely disposing of waste material while using it in the reclamation process to conserve fertilizers and soil amendments.

Special emphasis needs to be placed on the effect of mining on the hydrologic cycle and water quality. The availability of good-quality water for agriculture, municipal, and domestic uses is the most critical aspect of reclamation, particularly in the arid and semiarid sections of our country. We must determine the hydrologic and water quality conditions that exist in an area before mining, evaluate the effect that mining has on these, and develop procedures that will restore a desirable equilibrium.

When the above objectives have been met, we will have the technology to use our buried natural resources and to restore the surface land area. Whether this technology is applied will depend mainly on the will of the people. Implementation will involve an expense, which ultimately the consumer will probably pay. At today's prices, reclamation costs range from about $400 to $1,000 per ha. This adds an additional 10 to 15 cents to the cost of a ton of coal. But it is the price we must pay to meet the energy demands of a growing population while maintaining the quality of our environment.

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79.
Some General Problems of Soil Erosion of Disturbed Lands in the Caribbean

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The term West Indies refers to the chain of scattered Middle American islands extending east in a wide arc over a distance of 4000 km from Cape San Antonio at the western tip of Cuba to the island of Aruba just northeast of the Gulf of Venezuela. Today, the islands include Spanish, English, French, and Dutch speaking states, depending on their occupation from the 15th to the 20th century by Spanish and, later, by northwest European nations. A major feature of this occupation was the introduction of African slaves to supply cheap labor for a sugar cane plantation economy after the complete annihilation of indigenous Arawak and Carib Indian populations.

The Commonwealth Caribbean territories include the former British colonies in the West Indies and mainland South and Central America, which together with the U.S. and Canada constitute the English-speaking New World States. The Commonwealth Caribbean territories have recently established an economic trading community, the Caribbean Common Market (CARICOM).

In this paper, it will be shown that almost exclusive cultivation of plantation crops for export, which commenced in the 17th century, on flat and fertile soils with consequent relegation of food production for local consumption to areas with steeply sloping topography and poor soils have resulted in the major erosion problems of the region, and this pattern of cultivation persists to the present time.

TOPOGRAPHY, CLIMATE, SURFACE WATER, AND SOILS

Topography

As a result of the three different categories of relief of structural origin, i.e., faultblock mountains, volcanic mountains, and limestone plateaux, the Caribbean topography is varied. Thus, Hispaniola, Jamaica, and Puerto Rico in the Greater Antilles, which include extensions by the North American Cordillera system, are distinctly mountainous, while Cuba is dominated by extensive lowland plains of limestone origin. The islands to the windward in the Lesser Antilles may be divided into two groups: an inner mountainous chain of volcanic islands and an outer chain of low-lying islands, extending from Anguilla to Barbados. The islands to the leeward are mountainous due to the presence of an extension of faultblock mountains of the South American Cordilleras.

Therefore, apart from the Cuban plains and the small low-lying islands of the Bahamas and the Lesser Antilles, West Indian islands could be generally described as mountainous and therefore susceptible to erosion problems which are accentuated by climatic characteristics of the region.

Climate and Surface Water

The average temperature throughout the year at sea level in the West Indies is greater than 25° C because of the low latitudinal position of the islands (10° N to 25° N). Average temperature increases from 25° C in the Bahamas (25° N) to 27° C in Curacao (15° N). However, altitudinal temperature zones result from an average decrease of 0.5° C/100 m height. Accordingly, the Tierra Caliente zone up to a height of 900 m (average temperature >21° C), the Tierra Templada at 900–2000 m (21° C–16° C), and the Tierra Fria above 2000 m (<16° C) exist in the large mountainous islands of the Greater Antilles.

Average annual precipitation ranges from 11000 mm at higher altitudes in Dominica to 512 mm in Kralendijk, Bonaire, and varies not only from island to island but also within the same island. Thus mountainous islands, e.g., Hispaniola, Jamaica, Puerto Rico in the Greater Antilles, and islands of the inner arc of the islands to the windward receive more precipitation than flat islands, e.g., Cuba, the Bahamas, and islands of the outer arc in the islands to the windward, respectively. Annual precipitation also increases greatly over short distances with increasing altitude. On the east of Guadeloupe, precipitation increases from 2061 mm to 4414 mm with an increase in height, 230 m (20–250 mm) over a distance of 6 km and precipitation in Roseau, Dominica, (1928 mm) is much lower than at high altitudes (11000 mm). The amount of precipitation is also much higher on the windward than on the leeward side of most islands; annual precipitation in Port Antonio, Jamaica, is 3328 mm and in Kingston 732 mm.

Because of prevailing high relative humidities —up to 90%—and atmospheric instability, precipitation usually takes the form of short violent showers ranging in average intensity from 5.5 to 8.5 mm/hour in Guadeloupe. However, intensities over short periods (30–60 min) of 44, 77, and 90 mm/hour in the rainy season in Guadeloupe and up to 160 mm/hour in Jamaica have been recorded. Occasionally an intensity of up to 96 mm/hour has been recorded in the dry season in the Bahamas, indicating that precipitation of high intensity also occurs during the dry season in otherwise dry islands. High intensity rainfall is accompanied by strong, often gale-force winds. The West Indian islands, excepting Trinidad and Tobago and the islands to the leeward, are also in the path of the Caribbean hurricanes, which, apart from gale-force winds, could result in continuous rainfall: e.g., 728 and 3428 mm of rain were recorded in one and seven days respectively in Jamaica. Annual precipitation is normally distributed into wet and dry seasons, except in the wettest areas.

Because of the relatively small size, even of the islands of the Greater Antilles, and the minute size of the other islands, the mountainous topography of most islands and the characteristic patterns of rainfall distribution and intensity in the region, West Indian rivers are short and subject to great but brief fluctuations in water flow. Immediately after heavy showers, water flow is high, rivers are impassable and flooding with muddy waters occurs, resulting in considerable erosion and deposit of high sediment loads in sea waters of river mouths. However, a few hours after such showers, water flow often returns to its normally low discharge rates. Short, violent showers resulting in high river flow and flooding make West Indian rivers a serious agent of erosion, the effectiveness of which could be further increased by factors which increase surface runoff of water. Disturbance of original vegetation, particularly on hillsides, is the major factor responsible for increasing surface runoff of water and erosion problems in the region.

Soils

In a review of erosion problems in the Caribbean, Ahmad and Breckner (1973) reported that many of the soils on steeply sloping topography in Trinidad, Jamaica, and Barbados are developed on shales and schists and hence are susceptible to landslips and other forms of water erosion. Ahmad and Roblin (1971) also showed that even in flatter areas, e.g., in Trinidad, shale-derived soils are subject to crusting resulting from their high mica content, which in turn often leads to surface erosion. Some other erodible soils and water erosion problems—gullying, sheet erosion—dealt with by Ahmad and Breckner (1973) are summarized in Table 1.

Breckner (1973) also compared soil losses of three Tobago soils under vegetation-free experimental conditions on Goldsborough clay (formed on volcanic rock), Concordia sandy clay loam (formed on diorite), and Bloody Bay clay loam (formed on schist), on slopes of 10, 20, and 30° over a four-month period in the rainy season (rainfall 7.1 to 9.7 cm). Data indicated that soil losses which ranged from 116 to 236 ton/ha were highest on the Bloody Bay clay loam, but that the classical relationship of increasing erosion on increasing slope did not hold true on the wide range of slopes studied. Thus, on Goldsborough clay, there was a 41% increase in soil loss in the 20° compared with 10° slope but only an 11% increase on a 30° compared with a 10° slope on Concordia sandy clay loam. Moreover, on the Bloody Bay clay loam, there was an inverse relationship between soil loss and slope to the extent of a 94% decrease in soil loss on 10° compared with a 30° slope. These results were explained on the basis of reduced soil area exposed to vertical rainfall on steep slopes and hence reduced water available for erosion on such slopes. Data also showed that exposure, particularly in areas where strong winds prevailed, affected soil loss considerably and the lowest soil loss recorded, 17 ton/ha, occurred on a 30° leeward slope on Goldsborough clay.

Breckner (1973) also considered that the annual soil profile losses computed in those experiments (2.2 to 3.8 cm/year) indicated that the soils studied were more erosion resistant than other West Indian soils, e.g., the Bonnygate stony loam of Jamaica in which the entire profile could be lost in two to three years of cultivation (Finch, 1959).

In the arid and semi-arid islands of the inner arc of the islands to the windward—Antigua and Barbuda—wind erosion is sometimes prevalent (Hill, 1964). Such wind erosion problems are, however, often seriously aggravated by torrential rains which can sometimes occur after long periods of drought, when the land is unprotected by the sparse vegetative cover.

Therefore, topography, climate, and surface water, as well as soil type all contribute to the susceptibility to erosion of extensive areas in the West Indies.

NATURAL VEGETATION AND AGRICULTURAL CULTIVATION

Natural Vegetation

The flora of the Caribbean islands is varied because of local variations in climate with exposure and altitude and also because of edaphic variation. Beard (1949) classified the climatic plant formations of the Caribbean Tierra Caliente into: rainforest (in perhumid and humid climates—10–12 humid months); semi-evergreen forest (in semi-humid climates—7–9 humid months); and deciduous seasonal

TABLE 1. Some erodible soils and erosion problems in the Commonwealth Caribbean

Soil type	Country	Erodibility/Erosion problems
Sandy soils	Trinidad (a)	Very erodible
Limestone soils	Jamaica (c)	Erodible—landslides, gullying
	Barbados (d)	
	Carriacou (e)	
Shale derived soils	Jamaica (d)	Erodible—gullying
Shoal soils	St. Lucia (e)	Erodible
	Dominica (f)	
Clay soils	Trinidad (a,b)	Erodible—gullying
	St. Lucia (e)	
Volcanic tuffs,	Tobago (b,g)	Erodible—Sheet erosion gullying, slumping
Diorite and schists	Islands to windward, e.g., St. Lucia (e)	
Smectoid soils	Nevis (g,h)	Erodible—sheet erosion

(a) Chenery (1952).
(b) Hardy (1942).
(c) Stark, J. (1963), (1964).
(d) Cumberbatch (1969).
(e) Vernon and Carroll (1967).
(f) Lang (1967).
(g) Brown *et al.* (1965).
(h) Lang and Carroll (1966).

forest (in semi-arid and arid climates—3-6 humid months). The deciduous seasonal forest could be further classified into tropical deciduous forest, in areas with less than 1 250 mm precipitation and 5-7 humid months per annum, and thorn and succulent forest which receive less than 750 mm precipitation and have 3-4 humid months per annum. Variation in soil conditions also leads to edaphic plant formations in the Tierra Caliente, e.g., savannas, pine forests, etc. The increasing rainfall and decreasing temperature in mountainous regions result in montane plant formations, e.g., evergreen montane forests in the Tierra Templada and elfin woodland in the Tierra Fria.

Agricultural cultivation which was started by the Amerindians and continued on a greatly expanded scale by the early European plantation economy with its high demand for wood for sugar boiling houses and later "slash and burn" shifting peasant farming were responsible for decimation of high percentages of the natural vegetation of the Caribbean islands, particularly in Tierra Caliente zones.

Agricultural Cultivation

Because of the high annual rainfall prevalent therein, areas with tropical rainforest (10-12 wet months) and semi-evergreen forest (5-9 wet months) have been most extensively used for agriculture, particularly on flat or gently sloping lands. Three major systems of agricultural cultivation prevail in the West Indies: (a) large scale, monoculture, cultivation of crops for export; (b) small scale, polyculture, cultivation of crops for domestic use; and (c) extensive and intensive pastures. The water requirements of the export crops led to their cultivation in recognizable thermohygric climates (Blume, 1974) as follows:

Tropical rainforest—cocoa, coffee, bananas
Montane forest (10-12 wet months)—nutmeg, lime, ginger, vanilla, coconut
Semi-evergreen seasonal forest (7-9 wet months)—sugar cane, cotton, tobacco, pimento, pineapple, arrowroot, rice
Tropical deciduous forest (5-6 wet months)—sugar cane, bananas, with irrigation
Thorn and succulent forest (3-4 wet months)—sisal, sugar cane, and bananas with irrigation.

However, some plants, such as coconuts, are grown in both humid and sub-humid coastal regions. Use of irrigation can also extend the cultivation of crops into dry climatic zones. Sugar cane is the most extensively cultivated crop in the region and large-scale sugar cane monoculture enterprises in Cuba, Santo Domingo, Puerto Rico, Jamaica, and Trinidad are typical examples of such cultivation. Although usually cultivated on large farms, the listed crops are also grown by small farmers in the different Caribbean islands. The monoculture system of cultivation can therefore be classified according to dominant crop and size of farm.

The major food crops cultivated for domestic use in polyculture systems include: tubers (sweet potato, yams, cassava, tannia, taro); grains and pulses (maize, rice, red beans, pigeon peas, peanut); fruit trees (avocado, mango, breadfruit, plantain, papaya); and vegetables (tomato, cabbages, cauliflower, melongene, etc.). These crops are cultivated in all climatic regions, but especially in the areas of semi-evergreen and rainforests. Cultivation location is, however, largely dependent on edaphic factors since domestic crops are usually grown on soils unsuitable for export crops. In the flat islands, such farms form irregular patterns of penetration into the territory of large

farms according to the nature of the soil, but in mountainous islands, small farms on steep hillsides are separated from large farms on the flat by altitude. Small polyculture farms may either be based on tree crops or ground crops, or on irregular multicropping systems, such as in the Jamaican Central Range.

Blume (1974) defined large-scale farms (> 100 ha), medium-sized farms (20–100 ha), and small farms (< 20 ha) and classified the agrarian structure of the West Indies on the basis of farm size and distribution, as shown in Table 2, to indicate the dominance of large-scale and small-scale farms over medium-sized farms. Thus only in the Dominican Republic, Puerto Rico, Dominica, and Trinidad do medium-sized farms reach 15% of the area under cultivation.

Therefore, agrarian structure in the West Indian islands show both the extremes of dominance by large-scale (St. Kitts) and small-scale (Haiti) farm enterprises as well as several intermediate situations. One extreme or the other can be found in practically every island of the West Indies and in some islands (Antigua, Montserrat, Martinique, Nevis, St. Vincent, Guadeloupe, Haiti) both extremes exist and result in a very weak agrarian social structure. Where in addition the territory is mountainous, thus separating the small farms on the steep hillsides (Haiti, Jamaica) from the large farms on the flat, there is extreme danger of the existence of severe erosion problems.

EROSION PROBLEMS IN AGRICULTURE

Erosion Problems in Cultivation by Small Farmers

Shifting multicrop cultivation by small farmers on steep hillsides occurs to different extents in most mountainous islands of the Caribbean. Although practices and major crops vary slightly from island to island, the major features of such shifting cultivation include

1. Handcutting of bush cover using "a cutlass" or burning of vegetation towards the end of the dry season (February to April).
2. Land preparation by hand using a "hoe and fork" to produce mounds or rows with little attention to topography.
3. Planting of crops in mixed stand, e.g., tropical root crops, cereals, and pulses, at the beginning of the rainy season (May to June).
4. Hand weedings using a hoe after crop establishment.

TABLE 2. Classification of West Indian Islands according to farm size and agrarian structure (adapted from Blume, 1974)

	Farm size distribution			
		Large farms (> 200 ha) dominant		
Agrarian structure	Large farms (100–200 ha) dominant small farms > 10%	Small farms < 10%	Small farms > 10%	Large-scale farms dominant
1. >90% L.S.[a] farms	—	—	—	St. Kitts
2. >66% L.S. farms <10% M.S.[b] farms	Barbados	—	Antigua Montserrat Martinique	—
3. >50% L.S. farms	Grenada Jamaica	Tobago	Nevis St. Vincent	Cuba
4. 33–50% L.S. farms 33–50% S.[c] farms >15% M.S. farms (L.S. farms dominant)	Dominican Republic	Puerto Rico Dominica Trinidad	—	—
5. 33–50% L.S. farms 33–50% S. farms (S. farms dominant)	St. Lucia	—	—	—
6. >50% S. farms	Anguilla	—	Guadeloupe	—
7. >90% S. farms	—	—	Haiti	—

[a]L.S. Farms = Large-scale farms (>100 ha).
[b]M.S. Farms = Medium-scale farms (20–100 ha).
[c]S. Farms = Small farms (<20 ha).

5. After one to three cycles of such cultivation, the land is abandoned to bush fallow for periods varying from one to five years.

In such a system of cultivation, erosion is encouraged by the following factors:

—destruction of soil organic matter by burning;
—exposure of soil on steep slopes by clean cultivation at the beginning of the rainy season, before crop cover is achieved, when short and violent showers can occur;
—disturbance of soil structure by weeding both before and after crop establishment.

In these circumstances, a considerable amount of top soil loss by erosion occurs, leading to exposure of subsoil which is often more prone to erosion, and slower growth of after-crop cover vegetation in successive seasons. Eventually the land is abandoned in a practically unusable condition in which it is unable to support any vegetation.

Comparative rates of erosion under different land use systems ranging from 5 to 625 ton/ha/year in the non-limestone upland watersheds in Jamaica are given in Table 3. Blume (1974) estimated that up to 25% (91 000 ha) of the declared agricultural land in Jamaica was incapable of reafforestation or renewed agricultural use. It is suggested that a major fraction of such lands could have been made unusable by shifting cultivation. Although similar data are not readily available for other islands, similar or higher rates of soil destruction are likely to occur in Haiti (Wood 1963), and some of the mountainous islands to the windward, e.g., Montserrat (Lang 1967), Nevis (Lang and Carroll, 1966).

TABLE 3. Estimation of erosion rates under different land use systems in the non-limestone upland watersheds of Jamaica*

Land use	Soil loss (ton/ha/year)
Dense forest	5-12.5
Improved pasture	5-12.5
Cultivation	100-125
Bare slopes	375-625

*After Sheng, T., 1973. *Forestry Development and Watershed Management in the Upland Regions of Jamaica*

Small farmers also practice mixed farming by interplanting of several kinds of annual crops on the same piece of land to achieve year-round soil cover as far as possible or cultivation of tree crops and semi-permanent crops such as coconuts with bananas or coffee and cocoa with citrus and breadfruit. Although comparative quantitative assessment of soil losses in the three small farming systems are not available, there is no doubt that shifting cultivation results in the greatest quantity of soil loss.

Sheng and Michaelson (1973) conducted surface runoff and soil loss studies under yellow yam (*Dioscorea cayenensis*) cultivation which is extensively grown in certain mountainous areas of Jamaica. Comparison of different methods of land preparation indicated that soil loss under traditional cultivation, 134 ton/ha/year, was much higher than that in experimental treatments which were 27-39 ton/ha/year in two hillside ditch systems and as low as 18 ton/ha/year under bench terraces (Table 4). Surface runoff, 80-88 cm/annum, amounted to 30% of annual rainfall but was unaffected by land preparation treatments. Yield data (Table 5) showed that whereas total yam yields under bench terraces remained fairly constant at 33-45 ton/ha, those under traditional small farmer cultivation decreased sharply over a four-year period from 57-27 ton/ha.

Erosion Problems in Traditional Plantation Crops

Although there is no doubt that erosion problems in plantation crop cultivation are of a lower order than those in small multi-crop farming systems, these problems are nevertheless significant in view of the more extensive areas of land occupied by the former crops. Data (*FAO Production Yearbook, 1974*) showed that 2 862 × 10^3 ha or 27% of agricultural land are planted to the two most important crops in the West Indian Islands. With the exception of

TABLE 4. Soil losses and surface runoff in yellow yams (*D. cayenensis*) grown in hillside cultivation under different land preparation systems in Jamaica*

Treatment	Soil Losses		Surface Runoff	
	ton/ha/yr	cm/yr	cm/yr	% Total Rainfall
Bench terraces	17.48	0.51	86.66	32
Hillside ditch and contour mounds	26.63	0.79	88.39	33
Hillside ditch and hills	38.83	1.14	80.09	30
Traditional cultivation	134.35	3.94	79.76	30
Averages	54.32	1.60	83.73	31

*After Sheng, T. C. and Michaelsen, T., 1973.

TABLE 5. Total yield of yellow yams (*D. cayenensis*) in hillside cultivation under different land preparation systems in Jamaica[a]

Treatment	Yields (tons/ha)				
	Year 1	Year 2	Year 3	Year 4	Average
Bench terraces	35.8	44.8	33.0	38.3	38.0
Hillside ditch and contour mounds	39.5	45.0	40.3	37.8	40.6
Hillside ditch and hills	43.8	47.8	37.5	35.8	41.2
Traditional cultivation	57.0	53.8	33.5	26.8	42.8
Averages	44.0	47.8	36.0	34.5	40.6

[a]After Sheng, T. C. and Michaelsen, T., 1973.

maize in Haiti (320×10^3 ha) and rice in Cuba (195×10^3 ha) these crops are all traditional plantation crops including sugar cane, cotton, coffee, and cocoa, as well as bananas. Data from Jamaica (Sheng, 1973) showed that high percentages of these crops are sometimes cultivated on sloping lands (Table 6). Erosion problems in these crops are discussed below.

TABLE 6. Estimated acreages of major crops on sloping lands in Jamaica

Crop	Total Acreage	% Acreage on Sloping Land in 1970
Sugar cane	167 700	35
Bananas	84 000	90
Coconuts	137 500	80
Citrus	30 000	90
Coffee	15 000	100
Cocoa	32 000	100
Tree Crops	28 000	100
Ground provisions	18 200	100
Selected vegetables	15 000	80
Legumes	18 000	80
Other crops	11 200	50
Improved pasture	250 000	80
Total	806 400	—

Sugar Cane. Sugar cane is by far the most widely cultivated crop in the West Indies, occupying some $1\,911 \times 10^3$ ha or 18% of agricultural lands and 82% of the area planted to major crops ($2\,320 \times 10^3$ ha) in the region. Even if the high Cuban sugar cane acreage ($1\,600 \times 10^3$ ha) is omitted, e.g., in the Commonwealth Caribbean and French Islands, sugar cane acreage (173×10^3 ha) accounts for 19% of the area of agricultural lands and 30% of the area of the major crops in these islands. Most of these lands are on the fertile plains of the West Indian islands and account for 15 to 93% of the lands planted to arable and permanent crops (Table 7). This large acreage is, however, much smaller than the extensive sugar cane acreages in many of the islands, e.g., Haiti, the Commonwealth Caribbean and the French Islands at the height of the plantation economy based on slave labor in the 18th century. (Haitian export of sugar cane amounted to 15×10^3 tons in the 1960's, compared with 71×10^3 tons in 1789.) This reduction of sugar cane acreage was caused by increasing competition from sugar beets which forced marginal lands, that perhaps should have remained under natural vegetation, out of sugar cane production. These abandoned sugar lands, often on poor soils with sloping topography, have been the source of the most important erosion problems caused by sugar cane cultivation in the

TABLE 7. Important sugar cane lands in the West Indies and acreages as a percentage of crop lands[a]

	Major sugar cane lands	% of Crop land
Greater Antilles (Latin)		
Cuba	Camaguey Plains	45
Dominican Republic	Coastal Plain of Santo Domingo	15
Haiti	Plains of Cul de Sac & Leogane	20
Puerto Rico	Coastal Plains	24
Commonwealth Caribbean		
Jamaica	Southern Coastal Plains	26
Trinidad	Caroni Plains	27
Barbados	Throughout island	65
St. Kitts (LDC)	Coastal Plains and Lower Slopes	93
French Islands		
Guadeloupe	N.E. Coastal Plain	49
Martinique	Lamentin Plain	40

[a]Crop lands = Lands planted to arable and permanent crops (excluding pasture).

West Indies. Many of these lands, e.g., in Haiti, Jamaica and Trinidad and Tobago, already in a poor state with thin exhausted and eroded soils, were subsequently distributed to small farmers to be subjected to uncontrolled multicropping, leading to their further deterioration.

Hardy (1942) recorded up to 64% decreases in organic matter content (7.0-2.5%) in the 0-8 cm profile of soils under forest compared with those under sugar cane cultivation. Chenery (1952) reported that mechanization of cultivation and soil exhaustion through erosion, persistent monoculture, and reduction of pen manure application was responsible for the decline of the Noble Canes. The burning of sugar cane prior to harvesting, widely practiced in the Caribbean, apart from destroying soil organic matter, leaves the soil surface bare, exposed, and suceptible to erosion for several months of the year, including the period of the onset of the rainy season. Such burning, recently introduced to Barbados, led to a 4-ton/ha reduction in sugar yield and was subsequently declared illegal. More recently, Georges (1976) reported soil losses on sugar cane lands of varying slope in Central Trinidad of the order of 11.17 to 67.77 ton/ha on bare soil compared with 4.23 to 61.03 ton/ha under plant cane. Some 50% of the soil losses occurred before the establishment of the cane, and the range of variation of losses recorded was due mainly to soil series. It is worth noting that approximately 25% of the total sugar cane acreage in the West Indies, or 478×10^3 ha, is replanted every year, thus exposing the soil to potential erosion losses of the order mentioned above. In addition, the practice of interplanting replanted cane, e.g., with yams in Barbados and peanuts in St. Kitts, which could increase in the region, would lead to increased soil disturbance and soil exposure, thus aggravating the erosion problems in sugar cane cultivation. However, if burning is avoided in "ratoon" cane, the thick cover of dry leaves (cane thrash) protects the soil from excessive erosion. Accordingly, some Caribbean soils, such as in St. Kitts, have been continuously cultivated to sugar cane for more than 300 years and continue to give good yields today. Other soils—the heavy clays of Trinidad—under conditions of very wet rainy seasons and sometimes extended dry periods, give sugar yields of up to 100 ton/ha or 15 tons sugar/ha, a performance which perhaps could not be consistently matched by any other crop.

Cotton. Cotton cultivation has never occupied extensive areas in the West Indies, but recently Cuba has expanded its cotton acreage to the vicinity of 50 000 ha. Cotton cultivation utilizes similar flat lands to that occupied by sugar cane and has caused most serious erosion problems in the small dry islands. The long fallow period of the crop and its imperfect ground cover make cotton monoculture cultivation a serious erosion hazard. Fifty years of such cultivation has resulted in moonscape type terrain in Antigua and Montserrat in which soil exhaustion and soil erosion to parent rock are common features.

Coffee, Cocoa, and Bananas. In contrast to sugar cane and cotton which are for the most part cultivated on flat lands, coffee and cocoa are grown in mountain valleys on sloping lands. Banana cultivation occurs on flat and gently sloping lands mainly in Jamaica and the wet mountainous islands to the windward. These three crops have somewhat common erosion problems in that they all require a perhumid climate, give good ground cover when fully established, but are often cultivated on sloping lands (particularly cocoa and coffee) which are therefore susceptible to erosion problems.

The major erosion problems in cocoa, coffee, and bananas are caused by catastrophic events which destroy the normally adequate ground cover to lead to soil loss on exposed sloping soil surfaces with poor vegetative cover. Thus Caribbean hurricanes have led to crop destruction and erosion problems—coffee in Puerto Rico (1899), bananas in Jamaica (1951), cocoa in Grenada (1955). Rehabilitation after such disasters has taken several years and considerable funding. In Trinidad, cocoa cultivation has been seriously affected by the loss of its traditional shade tree (*Erythrina* spp) due to a fungal disease. Loss of shade has led to gradual loss of top soil due to exposure to heavy rains and it is claimed that such deterioration of cocoa soils was responsible for a 30% decline in the yield potential of this crop over the years. Even with proper shading, Hardy (1942) reported a 31% decrease (7.0–48%) in organic matter content in the 0–8 cm profile of soils when forest was converted to cocoa cultivation in Trinidad.

OTHER EROSION PROBLEMS ON DISTURBED LANDS

There are three other major agents of soil disturbance in the West Indies apart from agriculture:

Rural roads
Suburban landscaping for building
Mining

Rural Roads

Rural roads in the West Indies are often poorly constructed and unsurfaced. Indeed, many of them follow traditional traces without due attention to contour and topography. Accordingly, Sheng (1973) reported that approximately 50% of the 2 700-mile main road network in Jamaica was unsurfaced and, in addition, there were 4 500 miles of parochial roads and 2 600 miles of bridle paths. The majority of the

parochial roads were built in mountainous terrain, were unsurfaced, and suffered from erosion, bank slips and landslides. Also, runoff from roads sometimes dissected and destroyed farmers' fields. Thus, Sheng (1973) recorded that 10 cm of rainfall over a three-day period resulted in ten landslides in a 4-mile section of road. Such occurrences are not uncommon in rural areas on other islands during the rainy season.

Suburban Landscaping for Building

Cutting sloping land in suburban areas for road building and housing development often has been unprofessionally done and has led to severe erosion problems, to wall cracking and, in extreme cases, to collapse of new houses in "developed" areas, e.g., in Trinidad.

Mining

In Jamaica, surface mining of bauxite by the open pit method is done to a depth of 3–9 m. After mining, the area is required to be reshaped to a gentle slope and resurfaced evenly with approximately 30 cm of topsoil. In 1973, six bauxite companies owned about 7% of the land in Jamaica, but the area actually mined was comparatively limited. One company mined 22 ha per year. Davis and Hill (1971) reported that in the period 1953–1970, 1 480 ha of land surrounding mined-out pits were reclaimed at an average rate of 1.25 ha per ha mined. Sheng (1973) observed that at least two watershed protection problems were associated with bauxite mining:

1. "conservation of the spread but thin soil on mined-out slopes;
2. the threat of water pollution by red mud ponding, i.e., storage of tailings from processing bauxite to alumina."

Bauxite companies had started remedial measures to solve these problems.

Other mining operations in the West Indies—limestone, gypsum, stone and sand quarries—are operated on a small scale, but little attempt has been made to protect the disturbed sites from erosion. Also, in Trinidad a hillside recently has been extensively quarried to provide material for road building, with potentially dangerous landslipping problems for the main road and road users below the quarried area.

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The Influence of Soil and Climate on the Productivity of Grassland in Hill Areas

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Agriculture in hill areas is concerned with animal production and the basic problem of providing adequate nutrition from grassland. Inherent difficulties in current systems of production arise from the unequal distribution of pasture growth throughout the year, with critical shortages occurring in winter and early spring, and in variation in pasture production between years. Further problems arise for the agricultural adviser since almost every hill farm is unique in its combination of soil types, altitude range, slopes, and aspects.

The level and quality of production from indigenous grassland or moorland is low even when fertilizers are applied, and in Wales the emphasis has been on reseeding with more productive species coupled with improved management. This has been given further impetus in recent years with the successful development of surface-seeding techniques applicable to the more difficult wetter areas (Roberts, 1973). Only economic or social constraints limit further intensification which many believe will ultimately be necessary (Alcock, 1975).

As intensification increases there will be a need for much more detailed advice on what degree of improvement is economically justified at the individual farm level. Here the basic problem is to extrapolate from the limited experimental evidence obtained on pasture production at the higher levels of productivity to the varied conditions of soil and climate found in hill areas. Traditional field experimentation has become very expensive and the amount of research in hill land in the future is unlikely to be sufficient to solve the problems on an empirical basis. Indeed extensive experimentation may not be justified if a means of successfully utilizing the knowledge that has been accumulated in areas other than the hill environment can be developed. A first step towards this aim would be the development of a mechanistic model of pasture production. A model, based on physiological and physical principles, could be developed in parallel with limited but detailed experimentation carried out at a few centers. Such an approach has been adopted in the development of arid-zone agriculture (Van Keulen, 1975) and in the more restricted but considerably variable problem of fertilizer requirements in lowland vegetable crop production (Barnes *et al.*, 1976).

A systems approach to the multi-variate problems found in agriculture is attracting attention in a number of research centers and considerable developments in methodology have been achieved, (Thornley, 1976). Very often the adoption of this approach creates an immediate need for new experimental data. In hill land research, where this approach is very much in its infancy, the problems and objectives are only beginning to be clearly defined. In this paper, features of the soil-climate complex which are essential in determining pasture production in hill areas are outlined.

SOILS

The soils of upland Wales have been classified (Crompton, 1958) and an increasing proportion of hill land is being mapped at a level of detail necessary for an initial land capability assessment (Dermott, 1974), although much quantitative data regarding the physical and chemical properties of soils still remain unrecorded. The best soils from the production point of view are the acid brown earths and brown podzolic soils. It is on these soils that most of the early improvements have taken place. A high proportion of these well-drained soils are found on steeply sloping land (>10°) in the marginal ffridd (enclosed hill land) areas. At the other extreme for agricultural improvement are the poorly drained peaty gleys, and peaty-gley-podzols, found generally at higher altitudes than the brown earths and predominantly on more gentle sloping areas. It is this latter group of soils for which information is lacking and which represent a major area for future expansion of hill land productivity (Munro *et al.*, 1973).

All these soils in Wales are developed on Lower Silurian and Ordovician shales and mudstone sediments. The soil pH is inherently low, averaging about pH 4 for the peaty-gley-podzol and between 4.7–5.8 for the brown earths (Ball, 1960). The impoverished state of these soils is reflected in the low level of available (by analysis) phosphorus found in the top 150 mm which ranges from 4–6 kg/P/ha^{-1} with the lower amount found in the peaty gleys. Correcting the low pH and shortage of available P is an essential first step in hill land improvement. All these soils have an inherently low level of available nitrogen although some of the more fertile brown

earths have a much higher available N content than the peaty soils. This is an important factor contributing to differences in production of these soils.

The Use of Fertilizers

The most difficult areas for improvement are the peaty gley and peaty-gley-podzols. In 1959 the Agricultural Development and Advisory Service (then National Agricultural Advisory Service) initiated a long-term experiment on a peaty-gley-podzol at Nebo in North Wales (396 m). The object was to measure the response of surface-seeded pasture to annual spring applications of N, P, and K in the presence and absence of lime. Production was measured at the hay stage in early July and the experiment ran for 14 years. The main treatment effects averaged over the last ten for which full mineral analysis is available, are presented in Fig. 1. Lime was applied in 1959, 1965, and 1973 at the rate of 5 t/ha^{-1}.

Significant responses to N and P were recorded and although uptake of applied potash was high, the yield response was low—associated with the high availability of soil K. In the absence of lime the average soil nutrient supply was 12 kg P/ha^{-1} and 30 kg K/ha^{-1}. Liming had an effect on the floristic composition of the sward, the main feature being an increase in clover content particularly in the absence of applied N. The estimated average fertilizer replacement value of the clover was 58 kg N/ha^{-1} with a range of 26–94 kg N/ha^{-1}. Considering that only part of the growing season is involved this agrees reasonably well with the data of Munro and Davies (1974). The effect of lime was to increase markedly the recovery of applied phosphate and potash and to increase dry-matter production. This was probably associated more with the better establishment of the introduced grassland species than with soil nutrient availability.

These data are probably typical of many hill situations in that they demonstrate clearly the need for lime, phosphate and nitrogen.

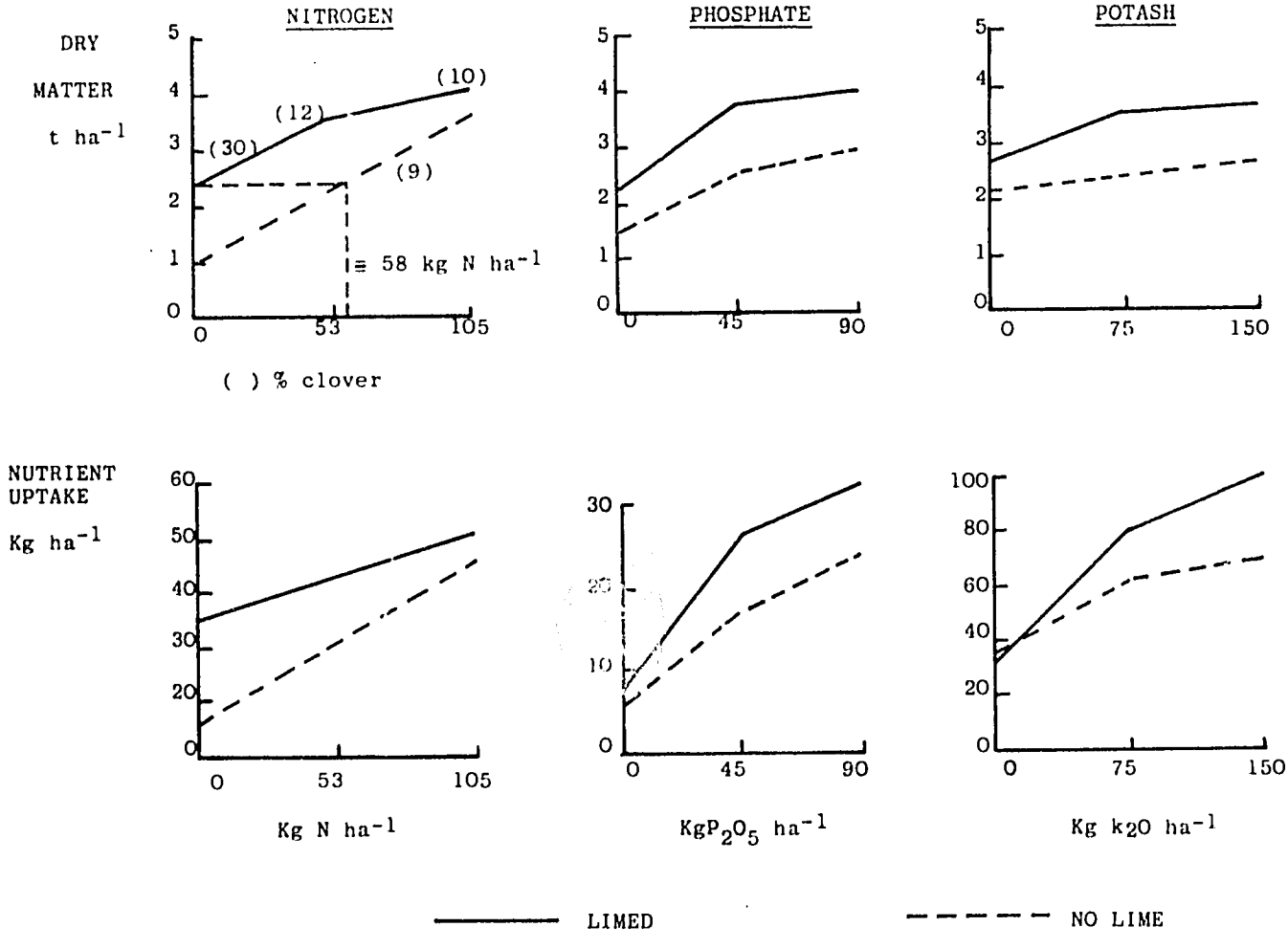
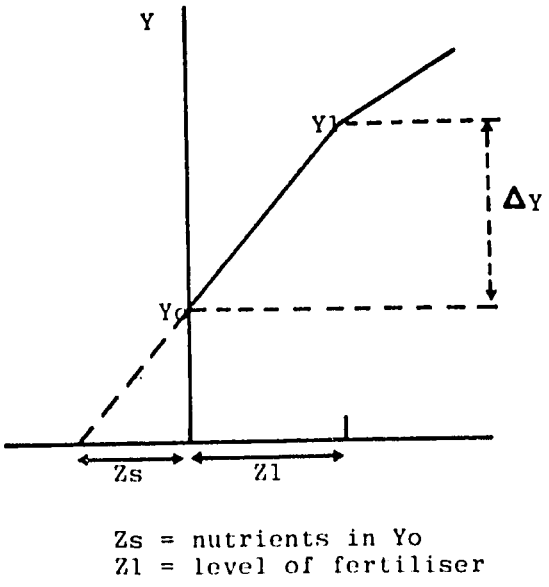


Figure 1. The effect of fertilizer nitrogen, phosphate and potash on nutrient uptake and dry-matter yield. Nebo experiment, A.D.A.S., Wales (unpublished data).



	Correlation of Y1 with		Coefficient of variation of ΔY
	Zs	ΔY	
NITROGEN - LIME	0.78**	0.64*	32.9%
PHOSPHATE + LIME	0.71**	N.S.	21.5%
- LIME	0.86***	N.S.	2.6%
POTASH + LIME	0.86***	N.S.	18.5%
- LIME	0.72**	N.S.	35.3%

Figure 2. Factors influencing variation in yield. Nebo experiment, A.D.A.S., Wales (unpublished data). (See text for explanation of diagram. N.S. = not significant, *P = 0.05, **P = 0.01, ***P = 0.001).

General Factors Influencing Variations in Yield

Assuming a linear response to a nutrient up to the first level applied in the Nebo experiment, the yield at *Y1* (Fig. 2) is dependent on (a) the response, (Δy), to the added nutrient (*Z1*), and (b) the level of nutrient supplied by the soil (*Zs*). Fluctuations in the yield of *Y1* between years will therefore be dependent on these two factors. A correlation analysis reveals that in the case of nitrogen, variation in dry-matter production was positively correlated with variation in the soil nutrient supply and the response to added N, while in the case of P, and potash, variations in yield were only correlated with variations in the soil nutrient supply. This agrees with Morrison *et al.* (1974) who point out that the largest responses to N occur in years of highest maximum production, and with the concepts of Bray (1954, 1963) and Russell (1972) which differentiate between mobile and immobile nutrients. In the case of the immobile nutrient P the yield responses are relatively constant from year to year, the higher yields being supported by an increased soil P supply which may be associated partly with increased root growth and partly with greater mineralization of organic matter in the more favorable years.

This point is further illustrated with four years' data selected to span the range of responses observed (Fig. 3).

If variability and size of the maximum response to a nutrient are sensible criteria for selecting that nutrient as a priority for further investigation then

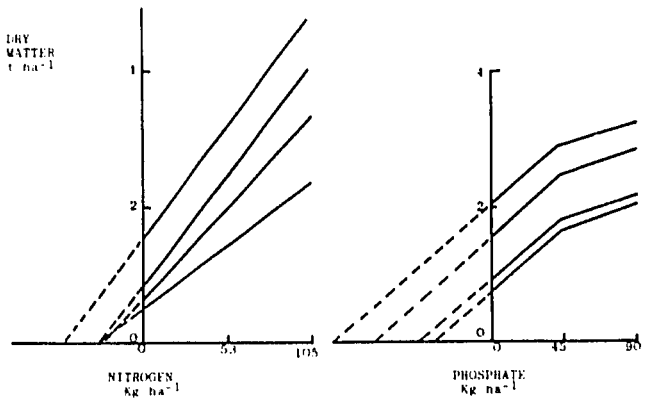


Figure 3. The effect of fertilizer nitrogen and phosphate on dry-matter yields. A comparison of annual responses (refer to text). Nebo experiment, A.D.A.S., Wales (unpublished data).

N is the obvious candidate. Although the use of N on hill land still remains low it is a major factor influencing productivity.

Factors Influencing the Response to Nitrogen

During the 14 years of the Nebo experiment the most variable component of the weather was rainfall. In this experiment the main period of growth occurred in May and June and in Fig. 4 the dry matter production is plotted against the rainfall total for the two months. Maximum yields coincide with a balance of rainfall and potential transpiration. Rainfall less than potential transpiration caused a marked

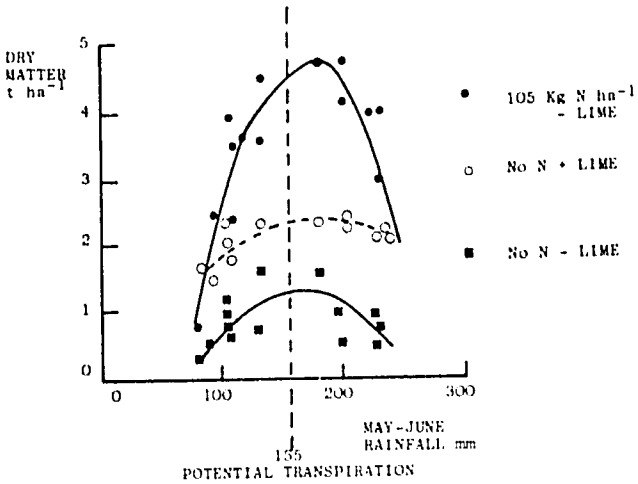


Figure 4. Influence of rainfall on dry-matter production. Nebo experiment, A.D.A.S., Wales (unpublished data).

drop in yield while rainfall in excess of potential transpiration also reduced yield. This indicates that both dry and waterlogged conditions can limit yield via reduced N uptake and reduced response to N. The precise mechanisms involved still require further investigation. In the absence of N and with adequate clover in the sward yield does not vary as much over the same period and the depression in the wet range is noticeably less marked. This agrees with general experience that white clover is far more tolerant of the type of adverse conditions found in this experiment.

Although not entirely independent, the response of pasture grasses to applied N can be considered in two stages. The first stage is the uptake of N. Fig. 5 shows a comparison of N uptake in perennial ryegrass managed similarly but growing on different soils and locations. A basic difference is seen between the lowland and hill data where N recovery is far lower in the latter situation. Differences in available soil N are widely found and, for example, Richards (1975) quotes a range of 13–334 kg/ha^{-1}, with a mean of 113 kg/ha^{-1} on lowland soils. In the hill situation a major difference is seen between the more fertile brown earth soil and the peaty gley and peaty gley podzol soils where in the latter the available soil N is particularly low. The second stage, the dry-matter response to plant N, is shown in Fig. 6. Up to a yield of between 3–4 t D.M./ha^{-1}, the dry-matter yield is limited by the level of plant N. Beyond a yield of 4 t D.M./ha^{-1} the dry-matter response becomes progressively limited by other factors which are presumed to be mainly climatic. The fact that data from two contrasting hill soils at the same hill site can be represented by the same curve suggests that the dry-matter response is under the influence of the common climate.

Alcock and Lovett (1968) in maximum crop experiments have compared the yield of perennial ryegrass

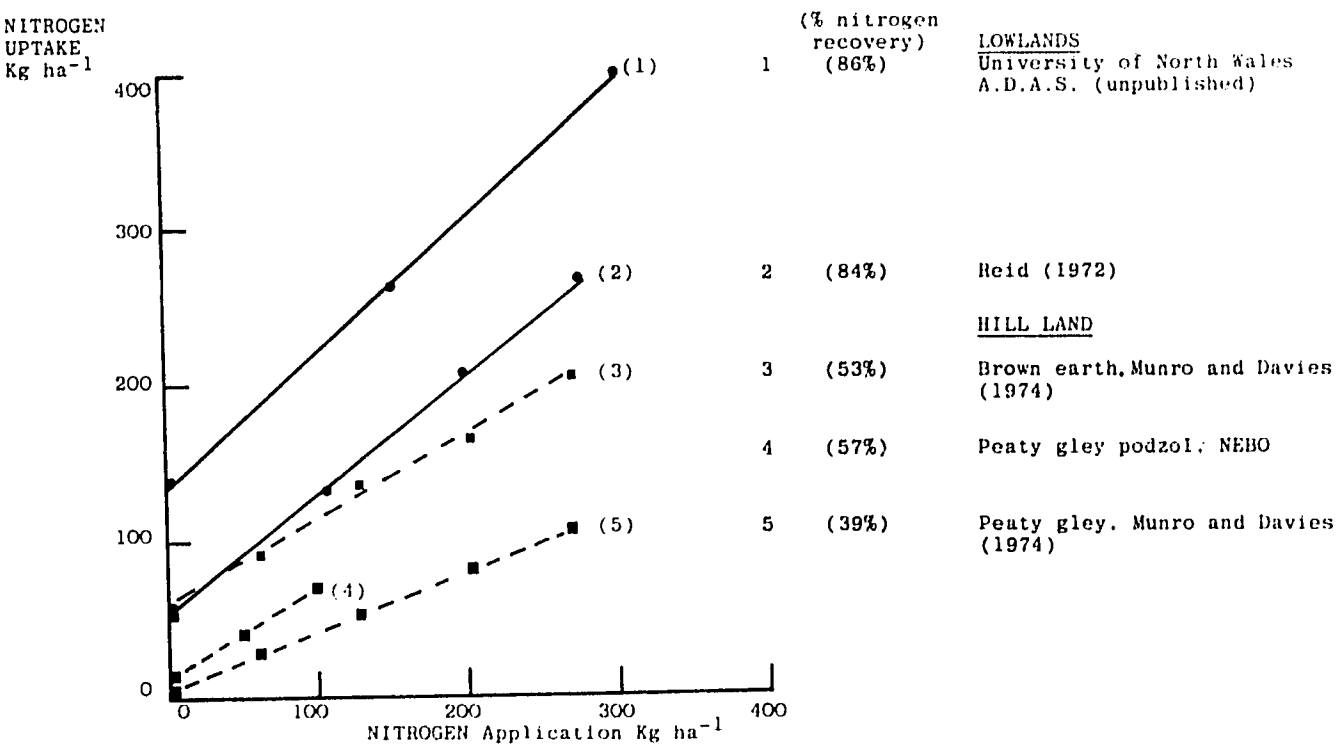


Figure 5. Effect of nitrogen application on nitrogen uptake in perennial ryegrass.

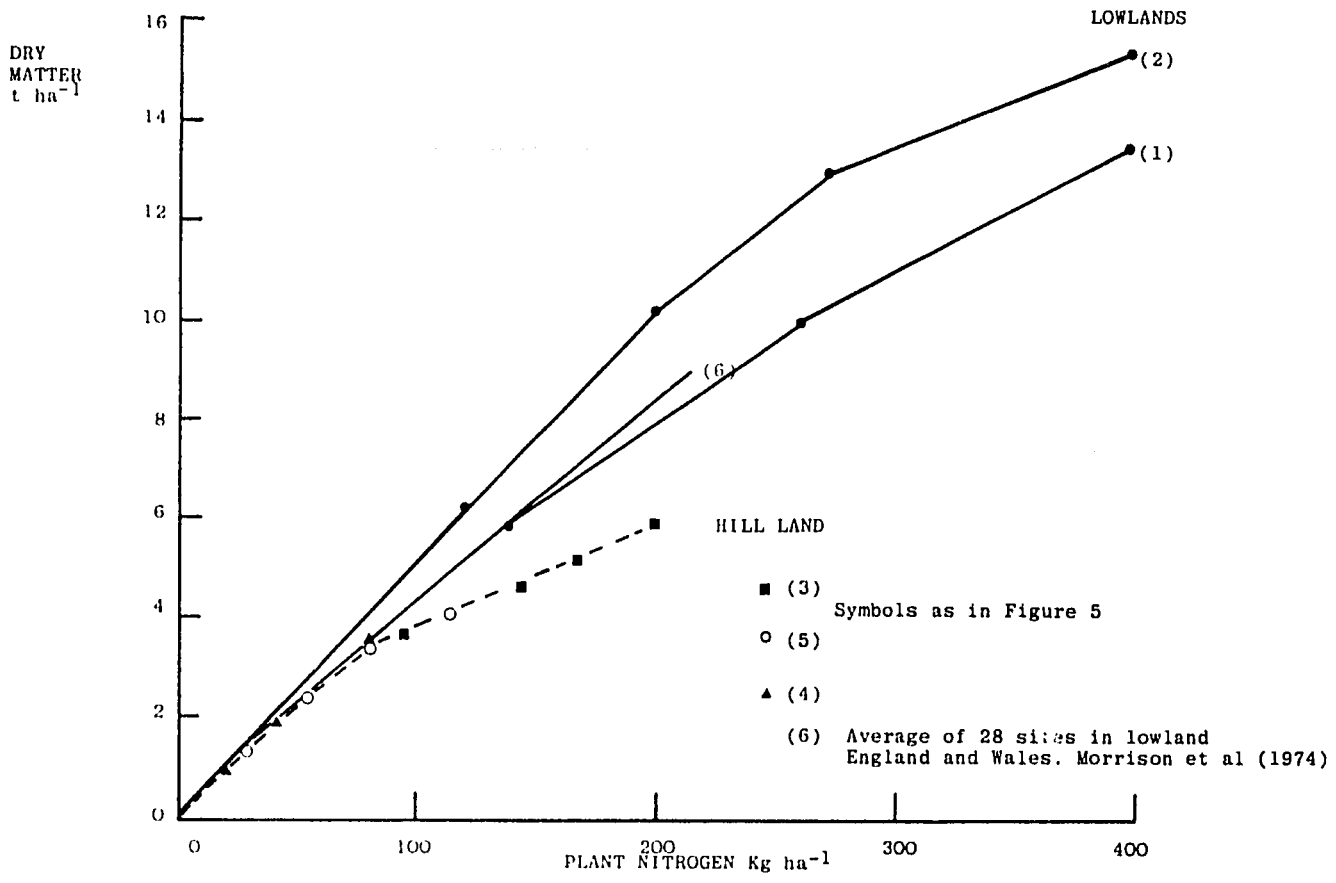


Figure 6. Response of dry matter to nitrogen uptake in perennial ryegrass.

on hill and lowland soils where these have been exchanged between the two sites. The results indicated that climate was the dominant factor influencing difference in production between the hill and lowland under conditions of non-limiting nutrients. Hughes and Munro (1968) using a similar technique also arrived at the same conclusion.

The poor recovery of N on the peaty gley soil, Fig. 5, has lead Munro and Davies (1974) to advocate dependency on clover for a source of N on this soil. The evidence from the peaty gley podzol suggests, however, that N recovery may not necessarily be so low on these organic soils, although it must be recognized that grassland management was different in the two experiments.

Clearly, the experimental evidence on the soil-pasture-nitrogen complex on hill land is far from complete and needs further investigation, particularly where the grazing animal is involved. The work of Richards (1975), in modeling the response to fertilizer N and clover under grazing conditions on the lowland, is particularly promising and has an obvious relevance in the present context in that it clearly indicates the need for quantitative information on such factors as the contribution of excretal N and clover N. The procedures adopted by Richards may also be applicable, with some modification, to the hill situation.

CLIMATE

Accurate measurements of the hill climate are particularly deficient, although in recent years in Wales a number of organizations have contributed to an increasing network of meteorological stations (Alcock, 1975). The danger has been that maximum extrapolation from limited sites has been attempted. In this way altitudinal gradients of various climate components have been used. For example, in Wales, a 100 m increase in altitude may result in an average decline of 0.64° C mean air temperature (ranging from 0.6–0.75° C, depending on season), 0.20 MJ m^{-2} solar radiation (ranging from 0.50–0.30 MJ m^{-2}, depending on season) and an average increase of 1.3 knots of wind (ranging from 1.0–1.8 knots, depending on season) (Smith, 1975). Such an approach, which has been used in a number of assessments of the climate conditions of largely hill areas, for example, Birse and Dry (1970), suffers from the obvious problems of local variation. Differences in aspect and slope can have important effects on soil

temperature; variations in hill contours and proximity to the sea can have a marked effect on wind speeds; local variation in cloud cover, slope, and aspect can influence solar radiation receipt. In the following discussion the data referred to are for specific sites, and a more general interpretation must be treated with some caution.

The effect of the hill climate on pasture production is complex and in order to isolate the more dominant components and their effects a simple relational model is adopted (Fig. 7). Pasture growth through the season is considered to be represented by a series of growth curves, the interruptions being due to defoliation. Each individual curve may be made up of as many as four critical stages, as this writer proposes, and are described below:

Stage 1. A net increase in dry matter accumulation commences with the attainment of a threshold temperature. Extreme water shortage in mid-season may also cause growth to cease and hence a soil water threshold has also to be considered, although this is less common. Although Stage 1 is indicated at a low yield, this condition is not restrictive.

Stage 2. Growth rates increase with time as leaf area increases. The duration of this stage depends on the rapidity of leaf development and on the size of the leaf system required for nearly complete light interception. Temperature, plant water status, and mineral nutrition are critical.

Stage 3. Approximately constant growth rates occur over a period when light interception is complete and the rate of growth of the aerial parts depends on individual leaf photosynthesis and canopy geometry, the respiratory load of the plant, and on dry matter distribution within the plant. Fluctuations in solar radiation can cause fluctuations in canopy photosynthesis, while rates of leaf photosynthesis can be restricted by water stress operating through increased stomatal resistances. Insomuch as only part of the aerial fraction of the whole plant is harvested, the partition of dry matter within the plant is crucial. This is influenced by the developmental state of the plant, i.e., whether in the vegetative or reproductive stage and by the water and mineral status of the plant. For example, Alcock and Hutchinson (1976) working with tall fescue found that variations in yield during the summer months were closely related to the effect of variations in soil water potential on dry matter partition, with more assimilates being diverted to the stubble and roots during dry periods.

Stage 4. Growth rate declines as a maximum yield is approached. The level of maximum yield is dependent on the amount of incoming solar radiation and on whether the sward is in a reproductive or vegetative stage. Towards the end of the growing season temperature will impose a limit on growth. During the growing season it is usual for grasses to be defoliated before Stage 4 is reached, while clover may be at Stage 4 for considerable periods in swards of high clover content.

Variations in the hill climate will now be considered in the light of the above observations.

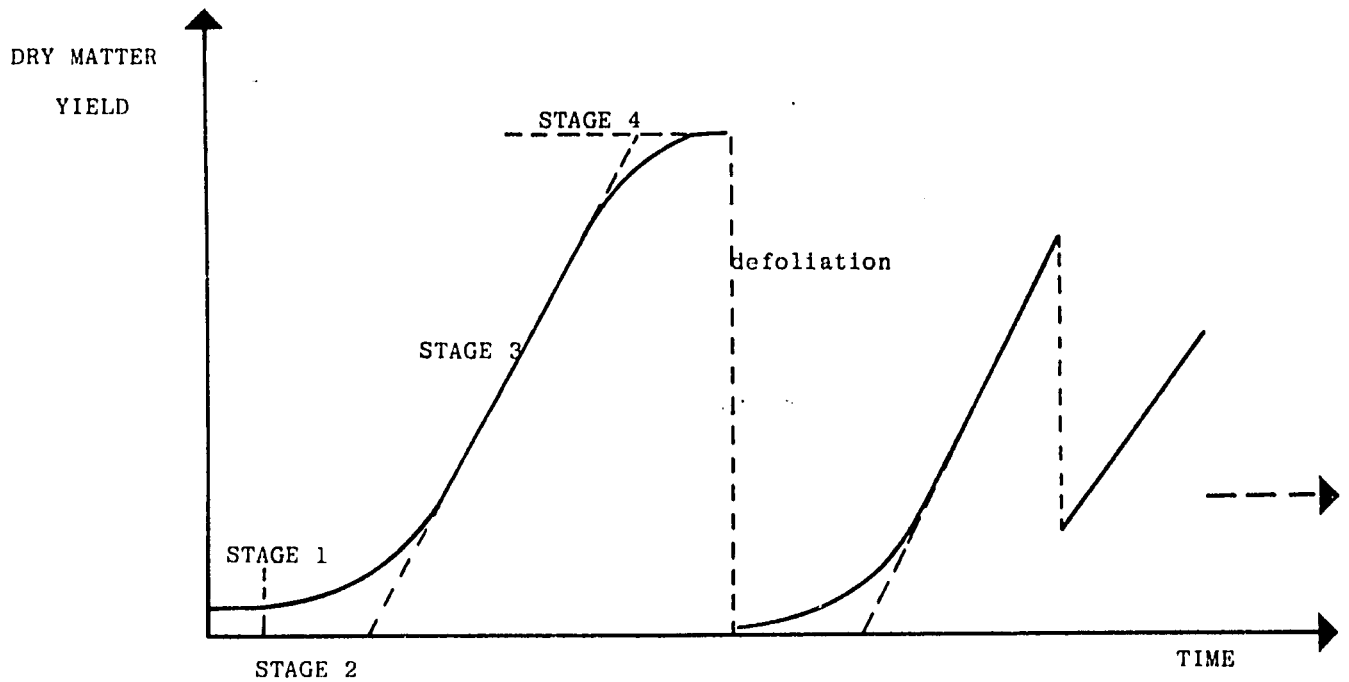


Figure 7. Stages in the growth of grassland (see text for explanation).

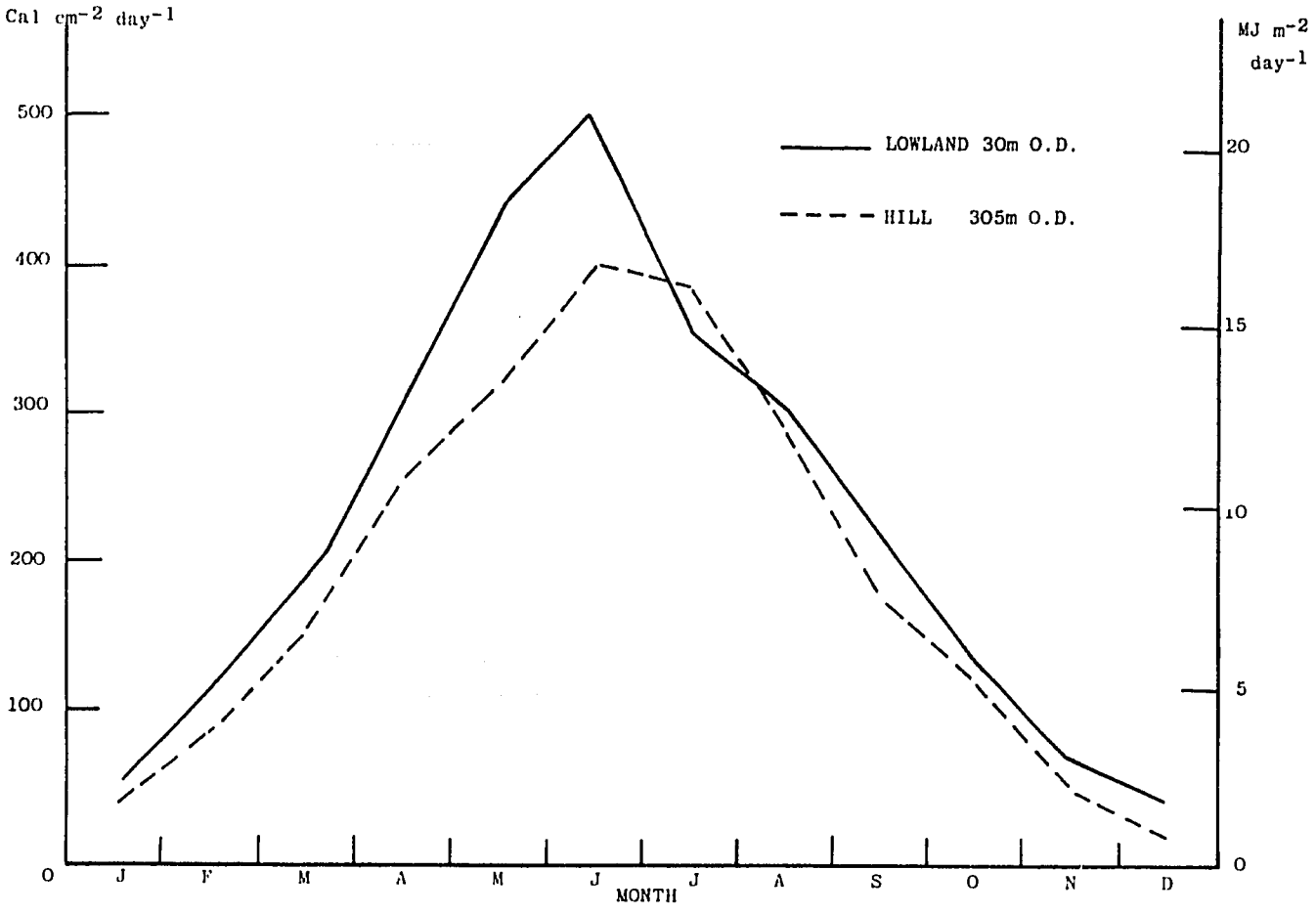


Figure 8. Solar radiation (adapted from Alcock, 1975).

Solar Radiation

Fig. 8, adapted from Alcock (1975), shows the annual range of solar radiation for a lowland site at 30 m and a hill site at 305 m. Radiation varies from about 1.6 MJ m^{-2} in winter to about 16.7 MJ m^{-2} on the lowland site in summer. In this comparison solar radiation is, on average, lower on the hill in the early and late spring months—a consequence of increased cloud cover on the hill. Using a model which predicts the growth rate of perennial ryegrass from values of solar radiation and simulated canopy photosynthesis, Alcock (1975) indicated that with a leaf area index of 6, applicable to stage 3, the maximum difference in solar radiation in June would result theoretically in a reduction in growth rate of 25 kg D.M. ha^{-1}/day^{-1}.

More recently an experimentally determined relationship between maximum pasture growth rate, including roots and shoots, and solar radiation has been obtained for tall fescue (Alcock and Hutchinson, 1976):

$$\text{Maximum growth rate (gm } m^{-2}\text{/day)} = -3.18 + 0.05 \text{ cal cm}^{-2}\text{/day}^{-1}$$
$$r = 0.95^{***}$$

Assuming that the experimentally determined value of 56% of total net assimilates used in shoot growth is applicable at both sites the predicted reduction in growth rate on the hill is 28 kg ha^{-1}/day^{-1}, which agrees closely with the theoretical estimates for perennial ryegrass.

It may be assumed that for much of the year the direct effect of reduced solar radiation on pasture production on the hill will be relatively small but could become significant if local variations result in pronounced reductions in radiation receipt or if prolonged periods of complete light interception occur.

Temperature

Seasonal changes of monthly mean screen temperature for a hill and lowland site are illustrated in Fig. 9. Although a soil temperature at a depth of 20 mm would be a more appropriate unit of comparison, there are considerable local variations in this measurement such as those caused by slope and aspect, and screen temperatures are probably more useful in giving a general classification of sites. Superimposed are threshold temperatures for the commencement of net growth (net dry matter accu-

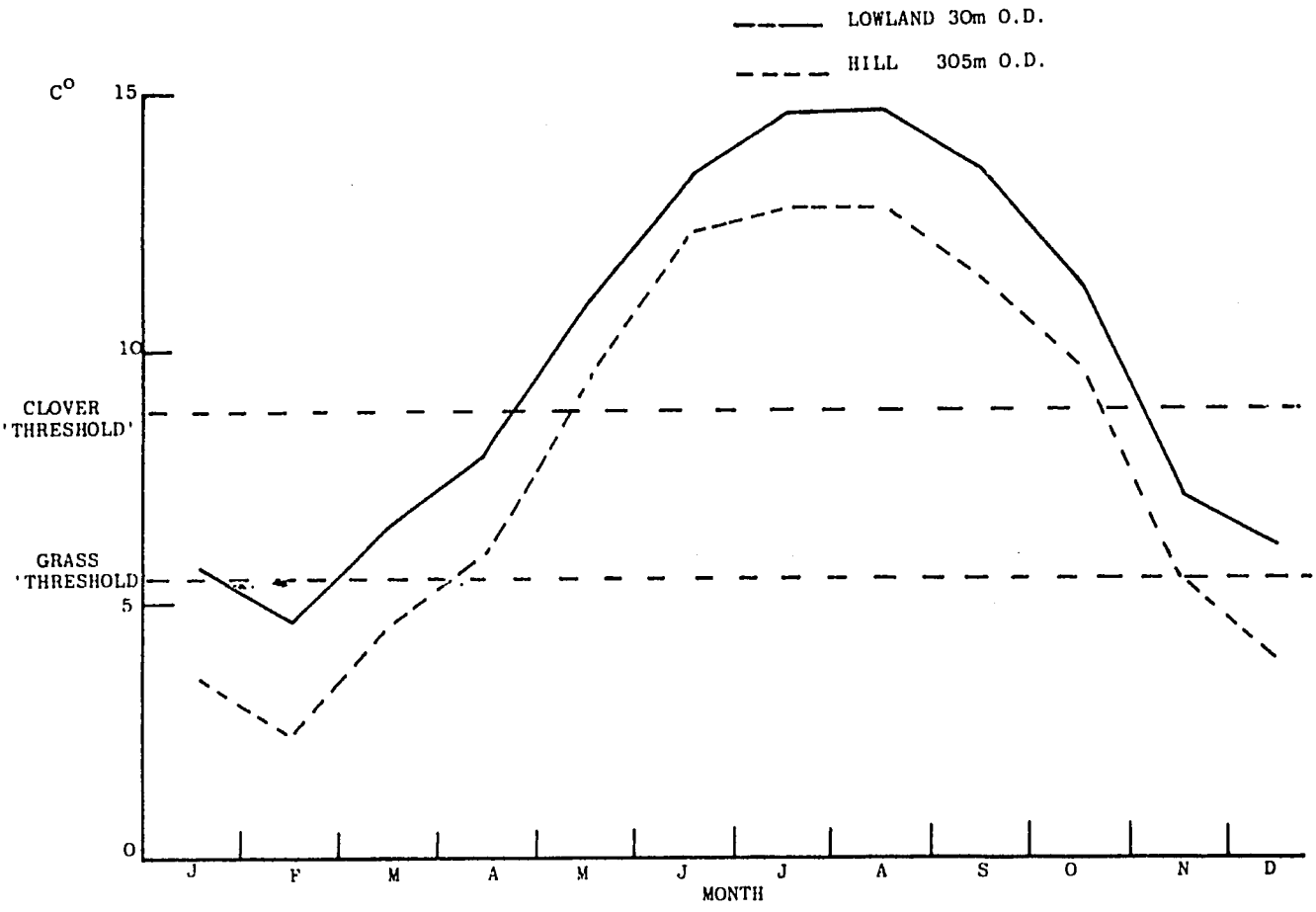


Figure 9. Monthly mean screen temperatures (adapted from Alcock, 1975).

mulation) of grass and clover (Stage 1). These compare well with the recorded duration of growth in the field (Fig. 10). The shorter growing season on the hill is a pronounced feature but subsequent growth is also temperature affected. Rates of leaf extension of grasses are closely related to temperature (Stage 2) and a comparison of hill and lowland, based on temperature and on published observations on the rates of leaf extension at different temperatures, indicates a reduction in growth throughout the season which is most pronounced in the spring months (Fig. 11).

In general, temperature is the major limiting component of the hill climate and exploitation of local site variations and the use of low temperature-adapted genotypes is an important aspect in hill pasture production. Lethal temperatures in winter can be significant for poorly adapted genotypes, particularly where the use of fertilizer has been intensified. In recent years winters have been mild and this problem has not been so evident, but if long-term changes in climate, which are predicted by a number of climatologists (Bryson, 1974; Lamb, 1974), materialize, then this aspect will become critical and indeed the implications for further reduced growth in spring are alarming.

Water Status

In general, as altitude increases so does rainfall. Changes in this occur owing to proximity to the sea and position relative to high mountains. Local variation in rainfall receipt can be influenced by minor variations in topography and proximity to tree shelter belts. Soil moisture, however, varies even more so, spanning a complete range from very dry soils where these are shallow and on south-facing slopes to waterlogged soils in depressions and where drainage is impeded. Despite a superficial impression that the hills are well supplied with rain, the fact is that short periods of water shortage are of regular occurrence and indeed much of the indigenous vegetation is xeromorphic in character. A detailed quantitative analysis of the water regime of hill soils is not available but the significance of this factor in influencing production is clearly seen in the Nebo data (Fig. 4). This peaty gley podzol has an impermeable layer at about 250 mm and the estimated available water capacity (0.1–15 bar) is only 74 mm

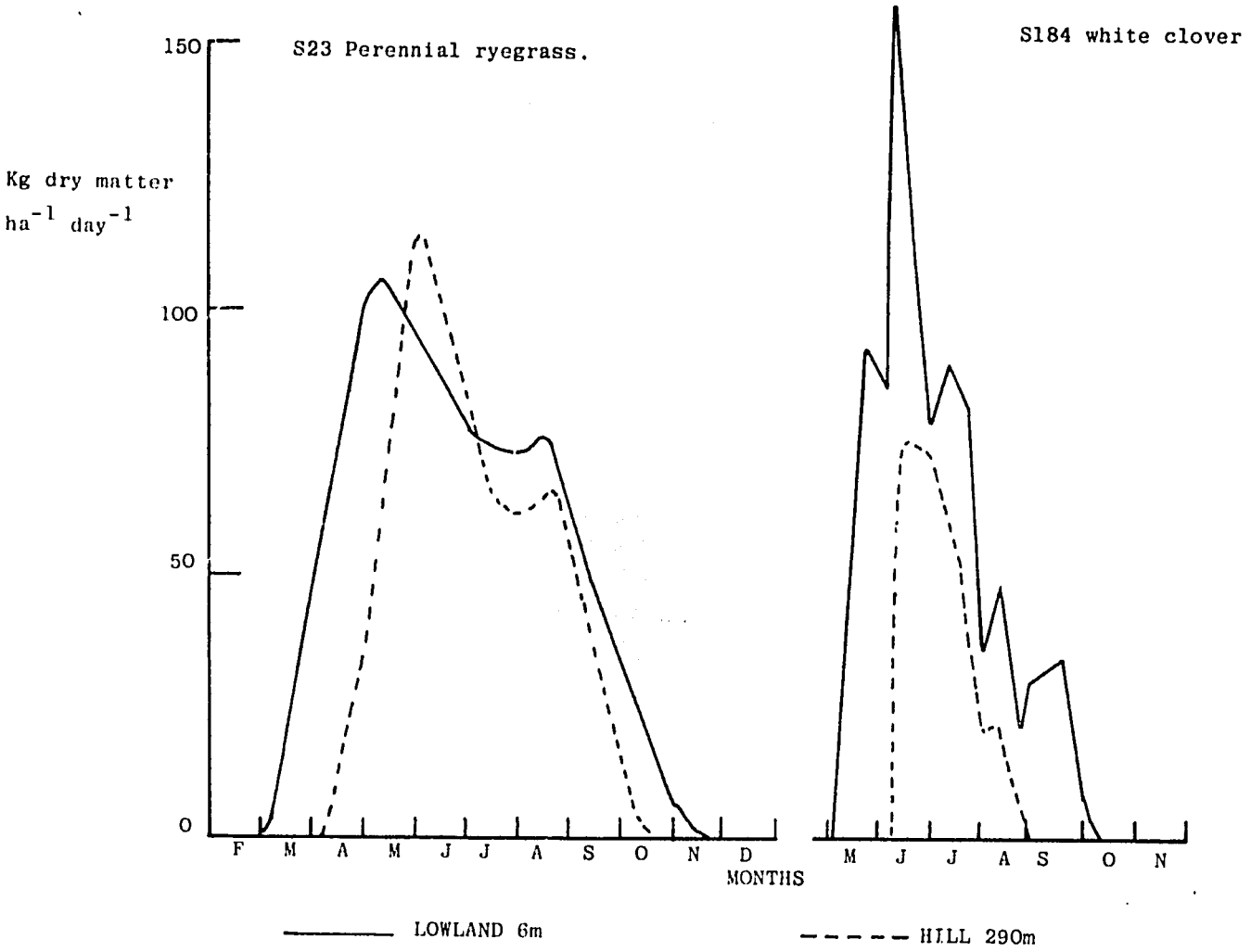


Figure 10. Seasonal changes in growth rate in maximum crop production experiments (adapted from Alcock, 1975).

(Rudeforth and Thomasson, 1970). This makes it very sensitive to variation in rainfall as the production data indicate. Variation in soil moisture and rainfall has a complicated effect on pasture growth in that both the mineral nutrient supply and plant physiological processes such as leaf extension and stomatal resistances (Stages 2 and 3) are influenced, while excessive leaching during the winter maintains an impoverished state of fertility.

The presence of more permanently waterlogged soils creates added problems which adapted species and drainage can only partly solve (Rogers *et al.*, 1973).

Frequently the question of the significance of increased wind speed in hill areas has been raised. Our evidence is that reducing wind speed by providing wind barriers can have the effect of reducing plant water stress and of increasing growth mainly when soil moisture deficits are not large (Alcock *et al.*, 1976). For example, the data in Fig. 12 illustrate the effect of artificial wind shelter on the percentage increase in growth rate and relative leaf water content of perennial ryegrass growing at a distance of 4 h from a barrier (h = height of wind barrier). Increases in growth arise from increased leaf area, during Stage 2, and greater partition of dry matter to the shoot during Stage 3. Not only is the soil water status important in determining the extent of the response but so also is the vapor pressure deficit of the air flow. If air is blowing from predominantly dry areas, then a maximum effect of shelter is observed. A full evaluation of shelter as a means of modifying pasture production is being made but as yet the work has not been completed.

ACKNOWLEDGMENTS

I am grateful to the Agricultural Development and Advisory Service in Wales for allowing me to use unpublished data, and to the Welsh National Water Development Authority for climatic data.

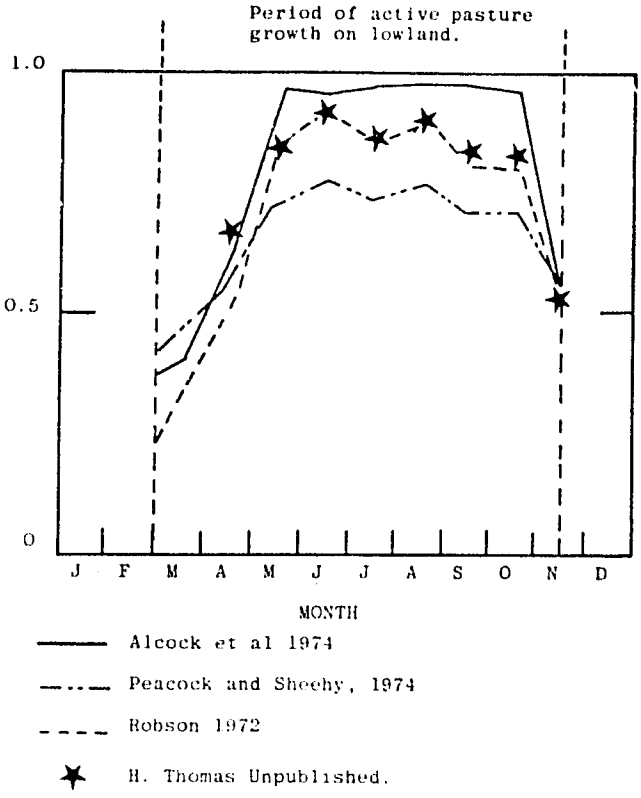


Figure 11.

$$\text{Ratio} = \frac{\text{Potential leaf growth at hill temperature}}{\text{Potential leaf growth at lowland temperature}}$$

for various estimates of the effect of temperature on leaf growth in grasses (from Alcock, 1975).

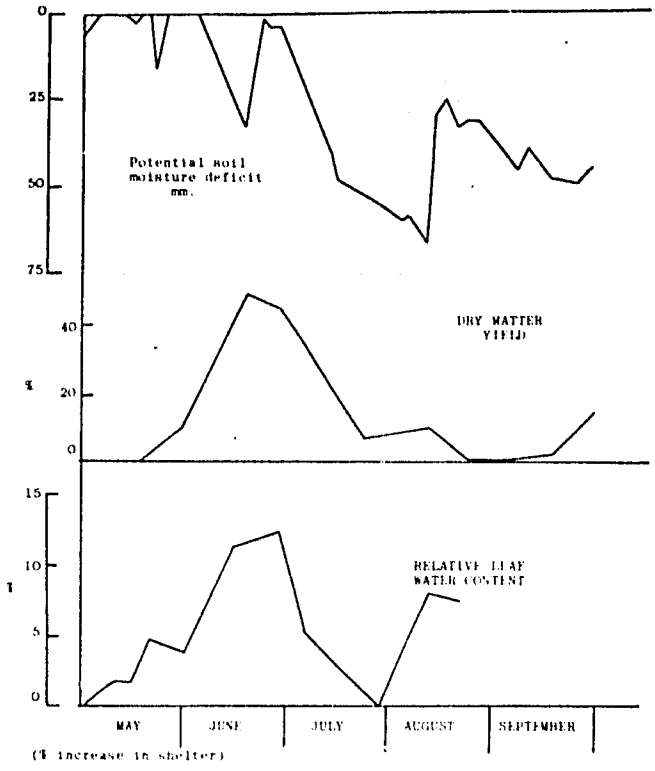


Figure 12. The effect of a wind barrier on perennial ryegrass growing at 290 m (after Alcock *et al.*, 1976).

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DISCUSSION

G. A. Jung (Pennsylvania, USA). There were two environmental parameters that you didn't mention that are quite important here. One is snow cover —where we toured yesterday the temperature is maybe −20, −30, −35° F in the winter months—but snow cover negates the effect of temperature and we have been able to demonstrate that cold sensitive cultivars of alfalfa can persist very easily and that management has very little effect under those conditions because snow cover provides protection through the winter and the plants are under much less stress because of snow cover and good water relations there than here. If you drop down to this elevation, the differences among cultivars and effect of management are quite dramatic. The other point is night temperature and the energy relations. In contrast to your situation, when we get into the middle of our summer night, temperatures are quite important in energy relationships. It's mediated, we found, through nucleic acids, and we wind up with a nutritive value of the forage in mid-summer here that is quite reduced because of our higher night temperatures.

Alcock. Thanks. I accept the point about the effect of snow cover. In my paper I have been mainly concerned with "normal" growth relations.Winter kill can be termed "catastrophic" growth which represents an important but complex problem which is outside the scope of my paper.

P. Henderlong (Ohio, USA). You mentioned or gave the radiation and temperature values for the hill vs low land area. Now, was this simply hill land at a high elevation or was there a slope exposure notation included in that?

Alcock. The temperatures were the mean air stream temperatures on a fairly level site. I think the slope effects would modify that considerably.

81.

Responses of Perennial Grasses and Legumes to Slope and Microclimate*

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Slope orientation and inclination largely determine the angle at which the sun's rays are received at the soil surface and, therefore, how they affect soil temperature and soil-water-plant relationships. Species adapted to a southern slope may not be adapted to a northern slope. In permanent pastures, species remaining in the sward may be influenced more by the microclimate created by the slope inclination and orientation than by management. Before field results obtained in hilly or mountainous terrain can be evaluated properly, the effects of slope inclination and orientation on microclimate must be recognized, measured, and interpreted for their influence on overall soil-water-plant relationships.

Slope-oriented differences in performance of forest species have been observed for many years in mountainous terrain. However, the effects of slope orientation on growth of forage species have only been examined cursorily (Marc-Deschenes, 1966; McKee *et al.*, 1965). Thornthwaite and Holstead (1954) pointed out that relief and exposure significantly affected the amount of radiation received by a given site. Cottle (1922) found marked differences in species composition on north and south slopes in Texas, which he attributed to water relations since he found that evapotranspiration (ET) was 24 to 66% higher and temperature was 6 to 12 C higher on southern slopes than on northern slopes. Vegetation density on southern slopes was less than half that of northern slopes

Fiatte (1951), who studied shale barrens in the Appalachian Region, found some interrelations between barrenness and slope-steepness and orientation. Barrenness generally increased with slope but did not occur at all on slopes of less than 20° and on north slopes. Moderately steep southern slopes and very steep eastern and western slopes were barren.

Marc-Deschenes (1966) found that differences in insolation on northern and southern slopes caused by the angle of incidence of the sun's rays affected soil moisture and temperature in grazed pastures in New Jersey. Southern slopes had higher soil temperatures and lower soil moisture contents than did northern slopes. Temperature differences were 2 C on newly seeded pastures and 1 C on old permanent pastures. The temperature and soil moisture differences between northern and southern slopes were slightly greater on steeper than on gentler slopes.

McKee *et al.* (1965) have observed that the direction a highway slope faces greatly affects the establishment, adaptation, and stand survival of sods: Kentucky-31 fescue grew best on the northern slopes and Bermudagrass grew best on the southern slopes. Wang (1963) pointed out that the duration and intensity of light striking the soil was greatly modified by slope orientation with respect to the sun. Heating and cooling of the soil surface were affected, mainly by solar radiation, long-wave black radiation, and convection.

Temperature directly affected growth and persistence of a given plant species through its influence on ET. As the soil and air temperatures increased, ET correspondingly increased. Hallin (1968) found that maximum soil surface temperatures increased as percent slope increased on southern slopes and decreased as percent slope increased on northern slopes on forest cut-overs in southwest Oregon. He found maximum surface temperatures of 71 C on southern slopes and 52 C on the northern slopes during August, 1964.

Controlling evaporational (E) soil-water loss is probably the greatest problem facing agriculture today. Evaporation from the soil surface generally accounts for 40 to 75% of the annual precipitation (Robins, 1961; Wendt, 1969). The remainder of the total soil water loss is accounted for by transpiration and by percolation and runoff.

Viets (1962) indicated that ET depends almost exclusively on meteorological conditions and is usually not affected by the nature of vegetation as long as the vegetation is green and completely covers the land surface.

Evapotranspiration is affected by both climatic factors and soil factors (Wendt *et al.*, 1970). Radiation, temperature, vapor pressure, CO_2, and wind ventilation (Lemon, 1966) influence both ET and growth of plants. The major soil factors affecting ET are fertility, soil moisture parameters, soil temperature, bulk density, and aeration. Therefore, we

*Cooperative studies by the Northeastern Region, Agricultural Research Service, USDA, Morgantown, W. Va.; West Virginia University Agricultural Experiment Station; and U.S. Pasture Research Laboratory, University Park, Pa.

must consider all of the above individual factors plus the total integrated effect upon the plant, since most of these factors are interrelated.

Penman's and Thornthwaite's formulas indicated that potential ET cannot exceed that of evaporation from a free water surface; however, Pruitt and Lourence (1968) reported that the ratio of ET to pan E for fescue and ryegrass at Davis, California, was about .80, except when winds and invection were strong. In comparing the standard weather bureau pan E with measured ET rates, Bennett and Doss (1963) and Doss *et al.* (1964, 1965) indicated that the ratio may be as much as 1:35 during parts of the growing season with cotton and several forage species.

During recent years, net radiation (Rn) has been used as a means of calculating potential ET (Doss *et al.*, 1964 and Doss *et al.*, 1965). In general, Rn depends on the optical properties of the surface reflectivity, emissivity, and surface temperature.

MATERIALS AND METHODS

During 1966 to 1969, field studies were conducted on north- and south-facing 30–35% slopes. The faces of the two slopes oriented within less than 5° of north and south directions. Soil on each slope was identified as Gilpin shaley silt loam, a member of the fine-loamy, mixed, mesic family of Typic Hapludults. Fenced experimental sites were about 1 ha on each slope. Five forage species were established on each slope: Common Kentucky bluegrass (*Poa pratensis*), Kentucky-31 tall fescue (*Festuca arundinacea*), Midland bermudagrass (*Cynodon dactylon*), Empire birdsfoot trefoil (*Lotus corniculatus*), and Chemung crownvetch (*Coronilla varia*). The Bermudagrass was planted by hand-sprigging at 30 cm intervals. Uniform stands of all species were obtained by the end of the first growing season but irrigation was required for the southern exposure. The sites were about 85 m apart. Species were established in a split-plot design with four replications. Slopes were used as main plots and species as sub-plots. Sub-plots were 2.4 by 3.7 m and were placed at the same elevation on both slopes.

Before plots were seeded, soils on all slopes were sampled by 15 cm increments to a depth of 45 cm to determine pH and available nutrient status of the soils. In addition, undisturbed core samples were taken at 7.5 cm increments to a 120 cm depth on all slopes to determine bulk density and moisture retention characteristics. Soil moisture tension curves were determined by means of a pressure plate and pressure membrane apparatus.

Before seeding, the soil on the southern and northern exposure was limed uniformly with 9 and 6.5 MT/ha, respectively to the soil test recommendations. Lime was incorporated to a 15 cm depth with a rototiller. Phosphorus and potassium were applied to all sites prior to seeding at a uniform rate of 77 kg P/ha and 140 kg K/ha. In addition, all grass species received an ammonium nitrate starter application of 112 kg N/ha. During harvest years, 77 and 140 kg of P and K, respectively/ha, were broadcast to all species before growth started in the spring and after each harvest. A total of 225 kg N/ha/yr was applied to grass species, one half before growth started and one half after first harvest.

First-year yields were taken for the three grass species after growth had virtually ceased in late fall. Forage was harvested one to three times/yr by clipping a 0.95 m swath through the middle of each plot. At the time of each harvest, a representative sample was taken of the forage from each plot for moisture determination and for chemical analyses. Yields were calculated on an oven-dry basis (65 C).

Beginning in 1967, soil moisture was measured gravimetrically in all plots. Soil moisture was determined for each 15 cm increments sampling to a 60 cm depth throughout the growing season. Evapotranspiration rates were calculated on the basis of available soil moisture found at each sampling date, plus the amount of rainfall received during a sampling period.

The following microclimate data were continuously measured on each slope: Maximum and minimum air temperatures at 1 m above ground; soil temperature at the soil surface, and at 2.54 and 7.6 cm depths with and without a cover of bluegrass or fescue; wind velocity; evaporation from a standard U.S. Weather Bureau evaporation pan; net radiation over bluegrass plots; and daily precipitation with a rain gauge.

Temperature of soil and Rn were measured with automatic recording equipment. Temperatures were measured using copper constantan thermocouples. Radiation was measured using Fritschen miniature net radiometers designed for recorders with disc integrators and totalizing counters.

Beginning in 1967, plant growth and incidence of plant diseases were noted at regular intervals on all plots. Identity and severity of plant diseases were determined (Bennett and Elliott, 1972).

During the first two years of the study, pure stands of each species were maintained by handweeding all plots. In the last year of the experiments, we made no attempt to control foreign species; but yields were adjusted to reflect only the percentage of the intended species present.

RESULTS AND DISCUSSION

Forage Yields

Total annual yields for each species are shown in Table 1. Seasonal yield distribution will be discussed. Only bluegrass, tall fescue, and Midland bermudagrass were harvested for yield determi-

TABLE 1. Yield of five forage species as affected by slope orientation

Species	1966		1967		1968		1969	
	North	South	North	South	North	South	North	South
				Kg/ha				
Kentucky bluegrass (*Poa pratensis* L.)	7745	2162	6948	3076	6867	3892	6812	2796
Tall fescue (*Festuca arundinacea* L.)	5875	3688	9803	10004	11636	11011	12756	11357
Crownvetch (*Coronilla varia* L.)			9236	9484	7982	6963	8605	11217
Birdsfoot trefoil (*Lotus corniculatus* L.)			6937	6142	6540	10152	7560	7139
Midland bermudagrass (*Cynodon dactylon* L.)	4475	11319	7708	11161	12081	12817	8406	17954

Statistical Analysis:	LSD .05		
Bet. Slopes	826 kg/ha	Slopes × Species	968 kg/ha
Bet. Species	443 kg/ha	Slopes × Species × Year	1015 kg/ha

nations in 1966 (Table 1). Birdsfoot trefoil and crownvetch grew substantially in 1966, but they were not harvested to allow for good establishment and winter survival. Yields from all three grass species were significantly affected by slope orientation. Bluegrass and tall fescue yields were highest on the northern slope while the Bermudagrass yield was highest on the southern slope.

Rainfall during the 1966 growing season (Fig. 1) was extremely low (74 cm), and plants on the southern slope suffered severely from lack of available soil moisture, while plants on the northern slope became established sooner, mainly due to the lower soil temperatures and more available soil moisture. The growth rate of Bermudagrass on the southern slope was much faster than on the northern slope. The dry conditions and high temperatures on the southern slope did not adversely affect normal establishment and growth of Bermudagrass.

In 1967–1969 yields of the five forage species varied considerably by harvest date and by exposures (Table 1). Total rainfall (Fig. 1) was near normal in 1967 to 1969 but distribution varied considerably. All forage species started growth more than three weeks earlier on the southern exposure than on the northern exposure. Nevertheless, Bermudagrass, except for yield distribution of the various forage species, was generally more even on the northern than on the southern slope. Bluegrass yielded significantly more on the northern exposures than on the southern exposure even though new growth was initiated first on the southern slope. Total seasonal yields of bluegrass for the four-year period averaged about 6800 kg/ha on the northern slope as compared to 3000 kg/ha on the southern. Only one harvest was made on the southern slope as compared with two and three harvests on the northern slope. Ac-

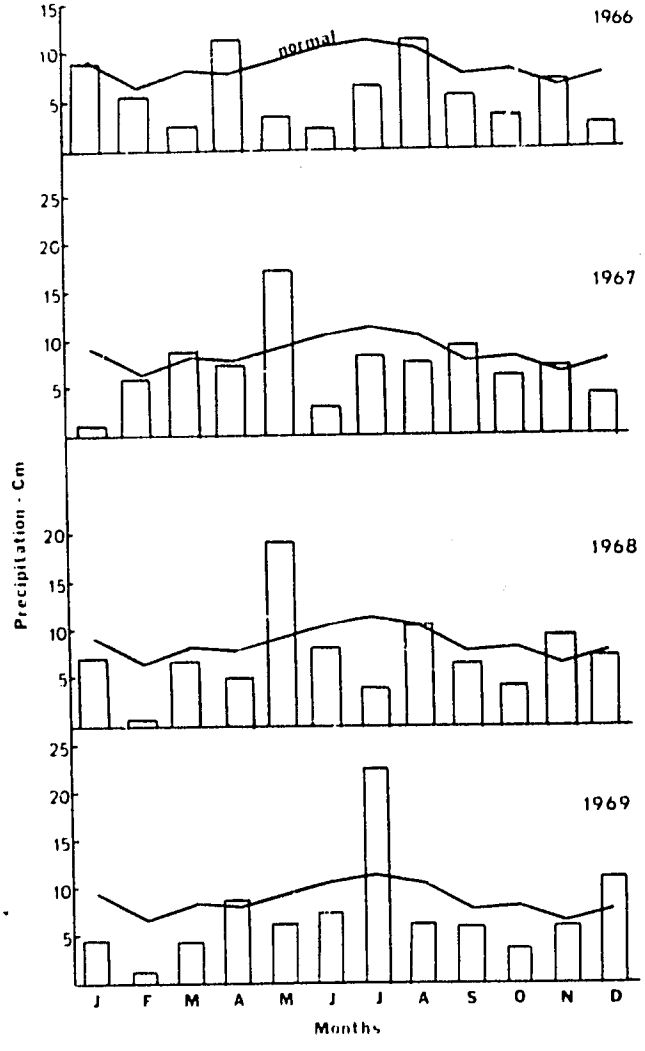

Figure 1. Total monthly precipitation, 1966–1969, with normal precipitation indicated by line graph.

tually, additional bluegrass harvests could have been made each year on the northern slope. However, root reserve accumulation was aided by not harvesting late in the growing season.

Tall fescue produced higher first harvest yields each year on the southern slope than on the northern, but second and third harvest yields were considerably higher on the northern slope than on the southern. Total annual yields were similar for both slopes. Tall fescue on the southern slope was adversely affected by high temperatures and low available soil moisture during mid-summer, but this species has the ability for rapid regrowth when environmental conditions are favorable.

Crownvetch yields were higher on the southern than on the northern slope for the first harvest each year but not for second harvest. Higher second harvest yields on the northern slope reflect the higher soil moisture conditions and lower soil temperature as compared with the southern slope. Exposure did not significantly affect total yields for the season except in 1969 when yields were higher on the southern slope. During the early part of the growing season damage from *Sclerotinia trifoliorum* may have caused the lower yields on the northern slope in 1969.

Yields of birdsfoot trefoil for the first harvest were generally higher on the southern than on the northern slope, reflecting the increased early growth from higher temperatures during the spring. In 1968 highest total yields were obtained on the southern exposure, reflecting more moderate temperatures and sufficient available moisture. In 1967 and 1969, total yields were not different between exposures, but plant populations differed significantly. Two harvests of birdsfoot trefoil were made during 1969 with no significant difference in yields between slopes at both cutting dates. After the second harvest on the southern slope, very few plants produced any regrowth and by the end of the growing season the stand of birdsfoot trefoil was almost completely lost. At the same time, good stands were still present on the northern slope. The loss of stand was mainly due to *Stemphylium loti*.

Midland bermudagrass, a semitropical species, survived the winters with temperatures as low as −27 C. Plants on the northern slope were usually protected by snow during much of the winter, whereas plants on the southern slope were subjected to a series of freezing and thawing cycles, which did not seem to damage the Bermudagrass. Total annual yields were usually significantly higher on the southern slope than on the northern slope. Midland bermudagrass produces a deep fiberous root system and, therefore, was less affected by drought conditions on the southern slope than the other plant species.

In 1969, Midland bermudagrass produced total yields of approximately 18 000 kg/ha on the southern slope as compared to 8 400 kg/ha on the northern slope. Over a period of time, bluegrass had invaded the Bermudagrass plots on the northern slope and about a 1 MT/ha crop of bluegrass hay was removed from these plots before the bermudagrass started growth in 1969. Even with the addition of the bluegrass to the total yields of the bermudagrass from the northern exposures, the yields were significantly higher on the southern slope.

Microclimatic Measurements

Radiation was the factor controlling all other microclimate measurements made during the study. Differences in soil and air temperature, E, ET rates, and even plant diseases and forage production were directly or indirectly related to radiation. Slope-oriented differences in radiation levels were measured throughout the experiment (Fig. 2). Net radiation (Rn) was always higher on the southern than on the northern slope for all months of all three years. Since total monthly Rn data were very similar for each of the three years, only the 1968 data will be given.

In 1968, Rn for the months of February, March, and April was more than twice as high on the southern than on the northern slope (Fig. 2). The amount of Rn measured on the southern slope in April, 1968, was higher than the amount measured during June on the northern slope. These radiation levels on the southern exposure in April were also reflected in higher soil temperatures for the southern slope.

Slope-orientation differences in Rn tended to decrease from February until June, when the longest days of the year were reached. The difference between north and south slopes increased near fall and winter. December and January often had negative Rn indicating more heat was being released from the soil than was absorbed from the sun.

Temperature Measurements

Temperature measurements for 1968 as affected by slope orientation are shown graphically in Fig. 3. Air temperatures were not sufficiently different (2–4 C) between north and south slopes to show them graphically, since lines were overlapping most of the time. Soil temperatures were usually highest on the surface of bare soil on the southern slope. Temperature differences of more than 23 C between the northern and southern slopes were found on the bare soil. Temperatures as high as 62 C were measured on the southern exposure at 2.5 cm with soil thermometers on extremely hot days when air temperatures reached 37 to 39 C. Even in midwinter, the maximum temperatures were as much as 14 to 17 C higher on the southern exposure than on the

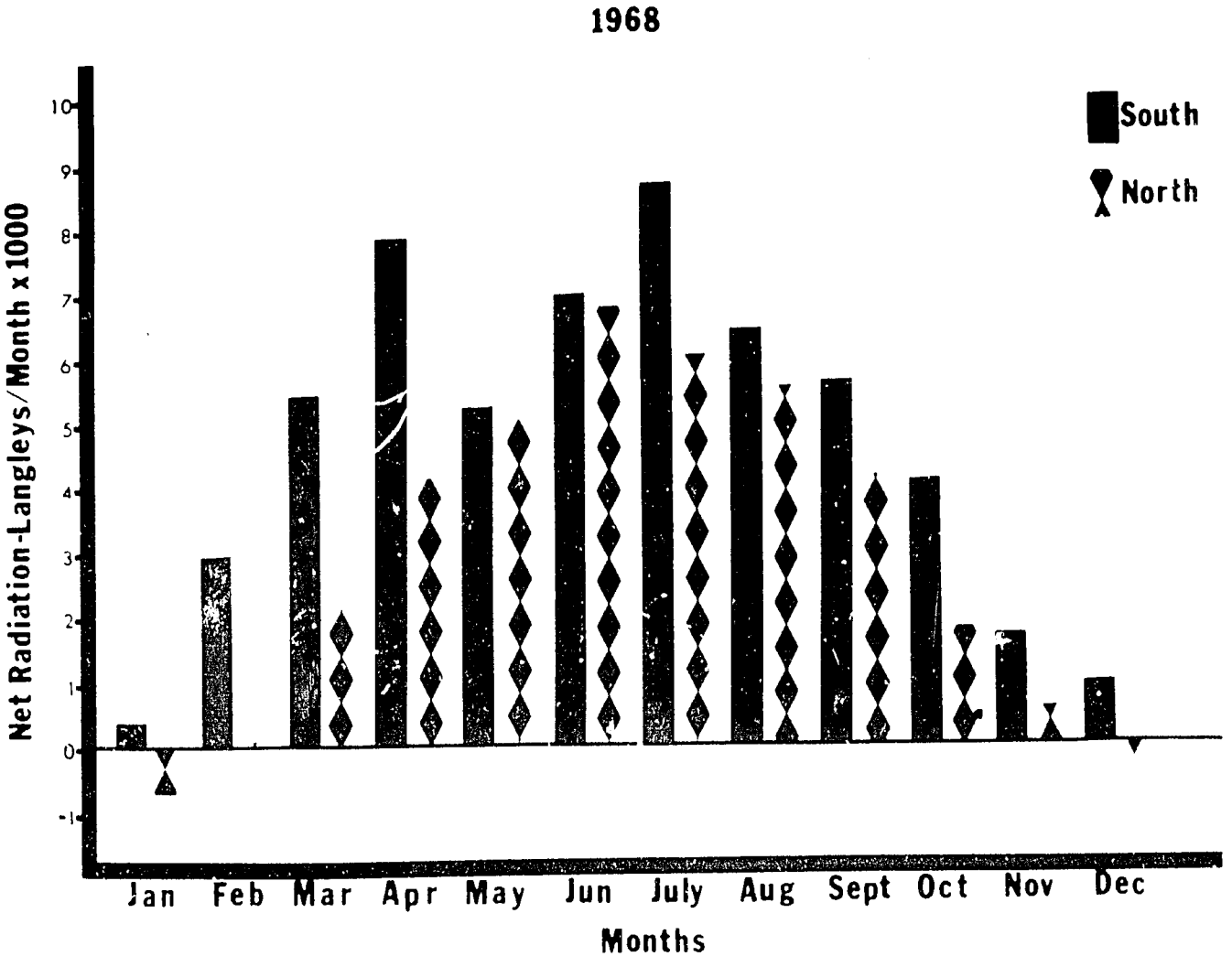

Figure 2. Effect of slope orientation on cumulative net radiation by months, measured at 1-meter height over a bluegrass sod in 1968.

northern exposure (Fig. 3). In 1968 the greatest temperature differences between north and south exposures seemed to be from mid-August through mid-November.

Differences in minimum soil temperatures between north and south exposures were more moderate. The greatest differences often occurred during the winter months as a result of the presence or absence of snow cover.

Maximum and minimum soil temperatures at 2.5 cm and 7.6 cm soil depths, either with or without vegetative cover, generally followed the trend of soil surface temperatures. Often during winter months, the minimum soil temperatures at 7.6 cm depths were considerably higher than minimum temperatures at the 2.54 depth, which was expected due to the cooler air temperatures during winter months.

Wind Measurements

Air currents can increase or decrease plant and soil temperatures, E, ET rates, and the rate of CO_2 exchange. Air movement may determine whether or not frost will form, or temperature inversions will occur. Wind was measured to determine its effects on some of these parameters.

Wind measurements show a significant negative relationship with radiation—when radiation was low, wind was high. Total air movement on the southern exposure was usually higher than on the northern exposure. Wind was always higher during the winter months and lowest during summer months.

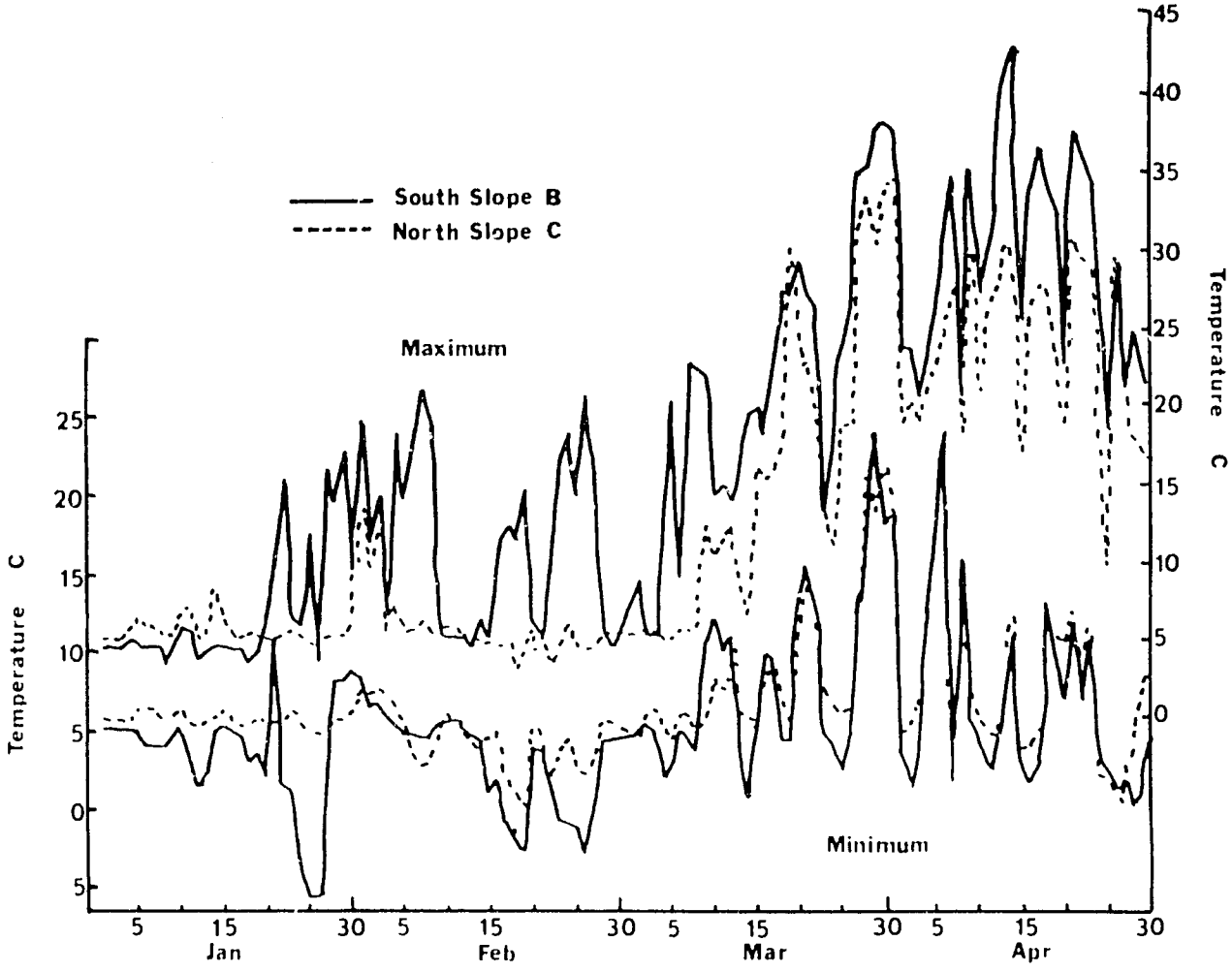

Figure 3. Maximum and minimum soil temperatures in bare soil at 2.54 cm depth, as affected by slope orientation.

Soil Moisture

Consistent and similar differences in soil moisture extraction patterns between exposures were found for all plant species throughout the experiment. Therefore, only the 1967 data are given in Fig. 4 for the five forage species.

The effect of slope orientation on available soil moisture content was highly significant ($P > .001$) due mainly to the differences in available soil moisture between north and south slopes for each 15.2 cm increment and for the total amount in the soil profile (0 and 61 cm) (Table 2). Soil moisture was always higher on the northern slope than on the southern slope. Differences in available soil moisture due to species were also highly significant for all three years. Bluegrass and fescue had widely different patterns of available soil moisture, especially in 1967. For two of three years, there was a significant interaction between slopes and species; however, during 1969 with normal rainfall, moisture use by species tended to be similar on both slopes. Since the available soil moisture was determined by the amount of precipitation and by ET rates of the various forage species, the significant interactions found for slope x sampling day, species x sampling day, and for slope x species x day would be expected. Evapotranspiration rates would not necessarily be the same for all species on both slopes on the same date. Furthermore, harvesting plants drastically altered the water use rates for several days afterward for a particular species. Available soil moisture content for bermudagrass, crownvetch, and tall fescue reached the lowest point about the same time that plants were harvested for yield. In 1967, there was a characteristic pattern whereby the soil moisture increased for several days after plants were cut and then gradually decreased until the plants were harvested again. The rate of change for soil moisture content depended upon slope and species.

The amount of available soil moisture present in the upper soil profile was one of the most important factors limiting growth and production of the five forage species on the southern slope. When the

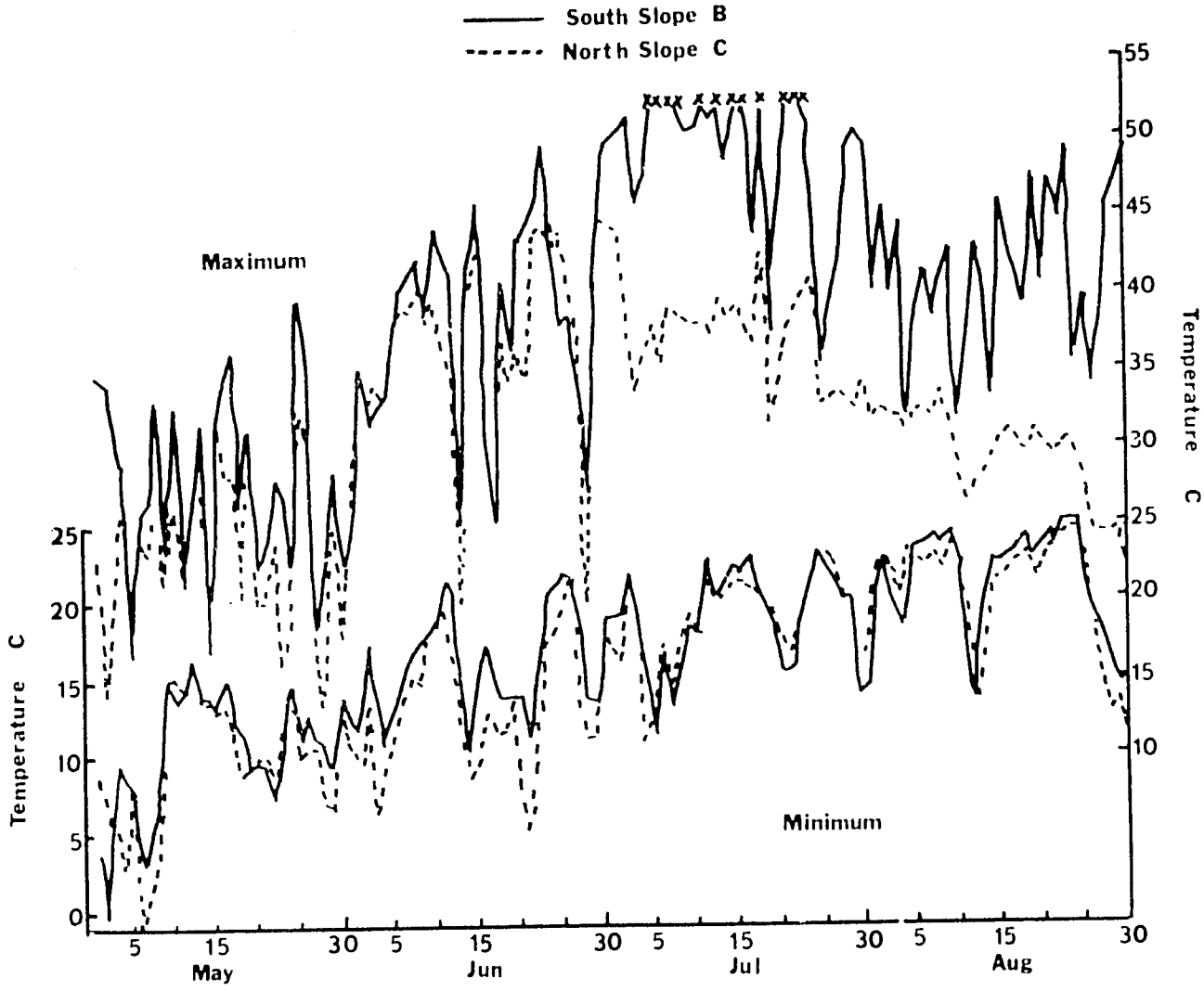

Figure 3 (Contd).

TABLE 2. Analysis of variance (F values and probability levels) for the effects of slope orientation on the available soil moisture content by soil depth, species, and sampling dates, 1967

Source of variation	Values for "F" and probability levels for each soil depth									
	0-15.2 cm		15.2-30.5 cm		30.5-45.7 cm		45.7-61.0 cm		Total (0-61.0 cm)	
	F[a]	P[b]	F	P	F	P	F	P	F	P
Slope	59.35	0.001	32.70	0.001	9.92	0.01	188.95	0.001	67.31	0.001
Species	8.60	0.001	33.07	0.001	27.49	0.001	44.89	0.001	57.33	0.001
Sp × Slope	3.64	0.005	8.44	0.001	2.08	NS	6.59	0.005	6.51	0.001
Day	70.83	0.001	71.24	0.001	52.09	0.001	93.39	0.001	177.82	0.001
Slope × Day	5.72	0.001	10.03	0.001	2.61	0.005	14.34	0.001	11.77	0.001
Species × Day	6.37	0.001	6.48	0.001	6.32	0.001	7.46	0.001	11.28	0.001
S1 × Sp × Day	2.27	0.005	2.14	0.005	2.68	0.005	3.02	0.001	2.26	0.001

[a]F Value.
[b]Probability Level.

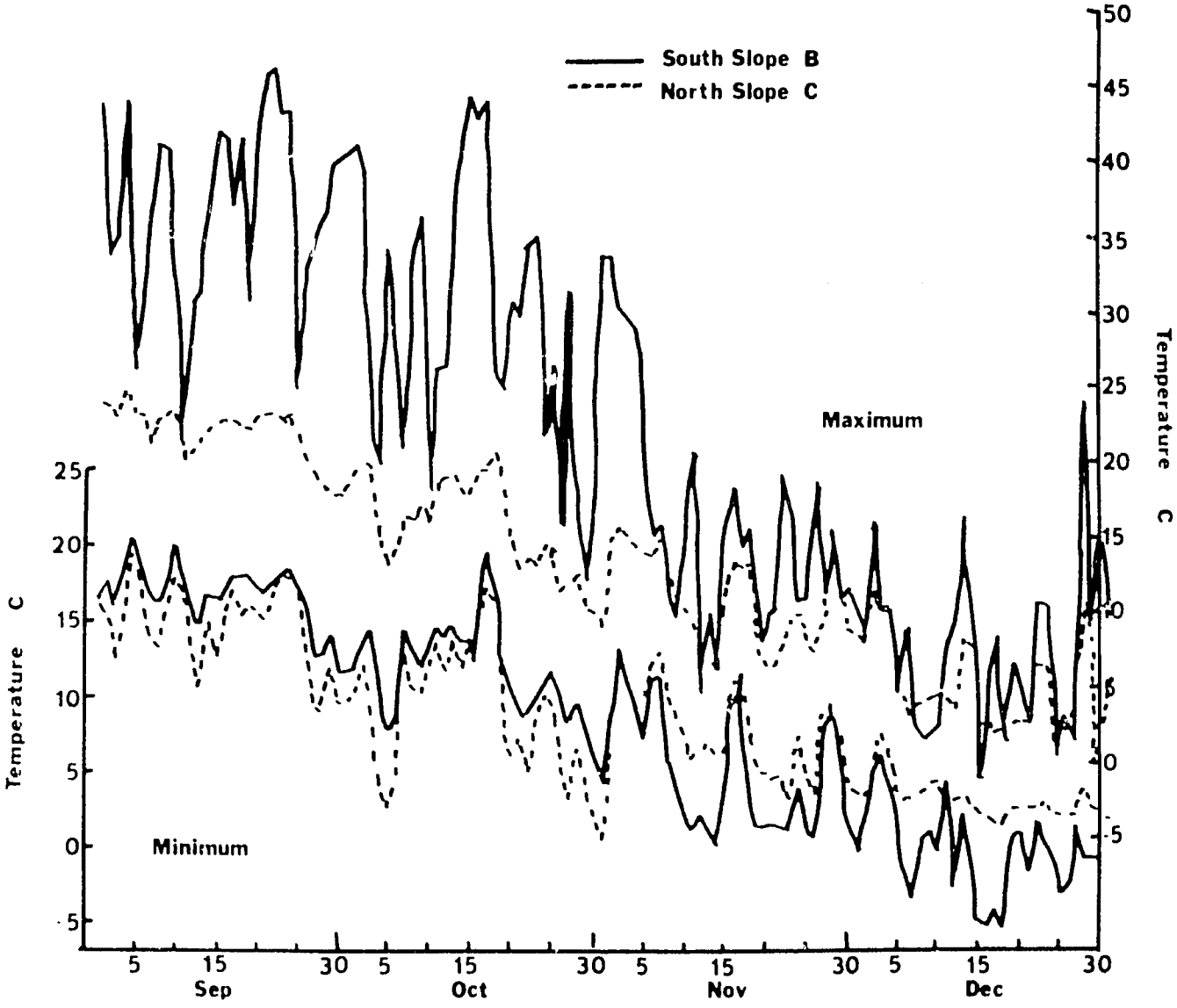

Figure 3 (Contd).

average available soil moisture content for all species and sampling dates are compared for each of the slopes, the average amount for the southern slope was usually less than one-half of that for the northern slope.

Evapotranspiration

The daily evapotranspiration rates (ET) varied with the amount of available soil moisture and with temperature (Tables 3 and 4). In general, the higher ET rates were found on the northern slope exposure because soil moisture was more available throughout the growing season.

Due to space limitations, ET rates are given for only bluegrass, a shallow-rooted species, and bermudagrass, a deep-rooted species.

Bermudagrass did not seem to be affected by lack of available soil moisture, even on the southern slope, as indicated by ET rates and plant appearance. Roots were found well below the 61 cm soil depth, which meant that the bermudagrass was extracting water from a much larger volume of soil than species such as bluegrass.

The average seasonal rates for all species in 1968 were about 10 cm/day higher than those in 1967, reflecting higher rainfall for 1968. The 1968 average ET rates varied from 0.32 to 0.36 cm/day with slightly lower rates on the southern slope for most species.

In 1969, rainfall during the growing season was near normal, and ET rates were high throughout the season. Average ET rates for the season showed little overall difference due to slope orientation with rates varying from 0.34 to 0.38 cm/day. However,

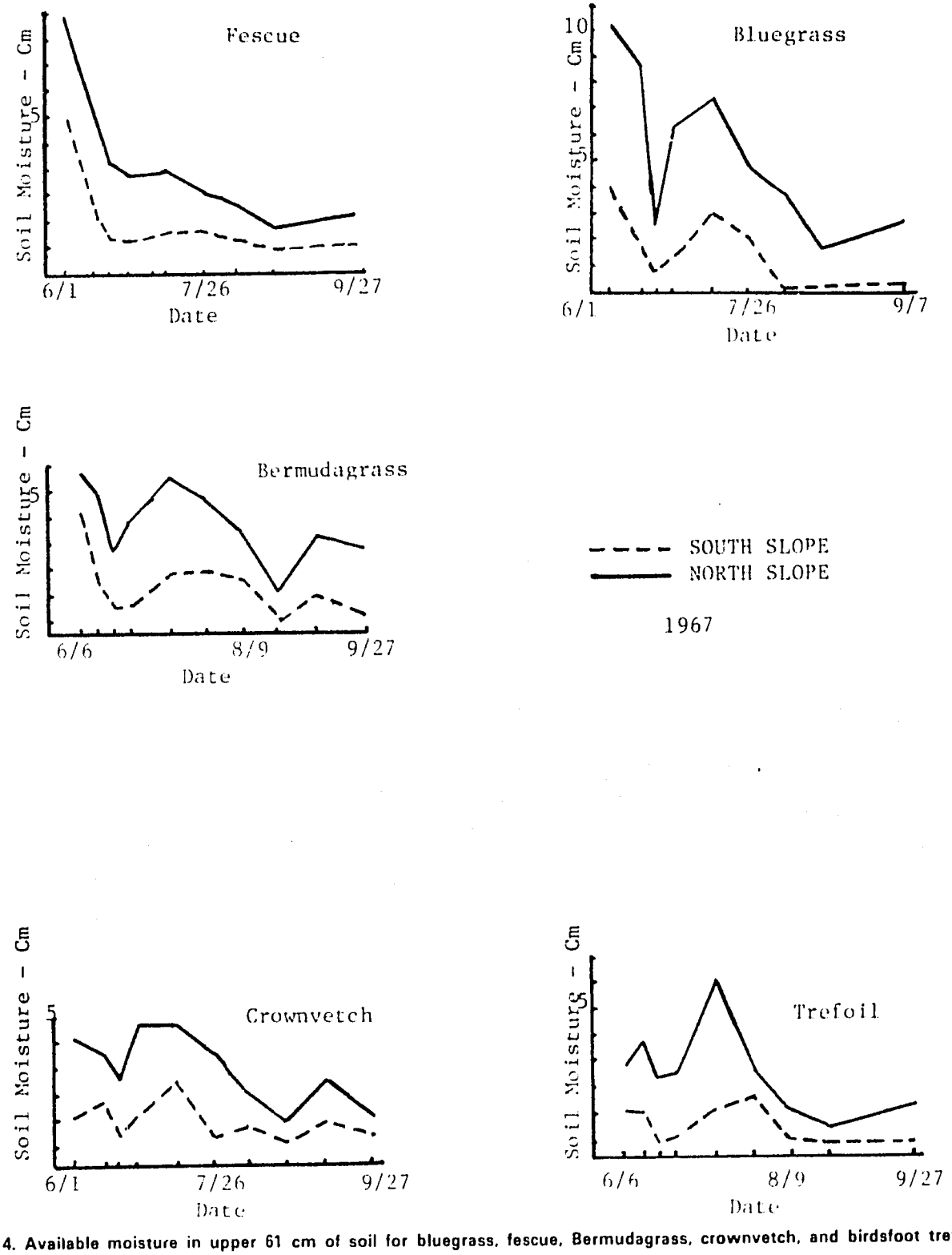

Figure 4. Available moisture in upper 61 cm of soil for bluegrass, fescue, Bermudagrass, crownvetch, and birdsfoot trefoil, as affected by slope orientation and sampling date in 1967.

TABLE 3. Average daily Evapotranspiration Rates (ET) for Bluegrass by growth periods as affected by slope orientation

Growth period	ET rates/day Southern slope	Northern slope
1967	*cm*	*cm*
06/01-06/13	0.19	0.22
06/13-06/19	0.15	0.63
06/19-06/26	0.27	0.59
06/26-07/12	0.21	0.25
07/12-07/26	0.30	0.43
07/26-08/09	0.29	0.26
08/09-08/24	0.06	0.24
08/24-09/27	0.25	0.23
Season Average	0.22	0.28
1968		
04/22-05/07	0.33	0.27
05/07-06/06	0.57	0.57
06/06-06/19	0.62	0.16
06/19-07/08	0.36	0.42
[illegible] 08-07/21	0.11	0.06
[illegible] 21-07/29	0.55	0.29
07/29-08/08	0.26	0.34
08/08-08/19	0.24	0.26
08/19-09/04	0.35	0.41
09/04-09/22	0.29	0.19
09/22-10/02	0.18	0.10
Season Average	0.33	0.32
1969		
05/19-05/27	0.20	0.20
05/27-06/17	0.23	0.31
06/17-06/26	0.14	0.24
06/26-07/02	0.33	0.30
07/02-08/22	0.45	0.40
08/22-09/05	0.27	0.18
Season Average	0.32	0.31

TABLE 4. Average daily Evapotranspiration Rates (ET) for Bermudagrass by growth periods as affected by slope orientation

Growth period	ET rates/day Southern slope	Northern slope
1967	*cm*	*cm*
06/06-06/13	0.38	0.36
06/13-06/19	0.17	0.17
06/19-06/26	0.33	0.17
06/26-07/12	0.25	0.22
07/12-07/26	0.26	0.32
07/26-08/09	0.18	0.24
08/09-08/24	0.09	0.05
08/24-09/08	0.41	0.24
09/08-09/27	0.18	0.16
Season Average	0.24	0.23
1968		
05/07-06/19	0.60	0.61
06/19-07/08	0.17	0.42
07/08-07/17	0.11	0.14
07/17-07/21	0.17	0.19
07/21-07/29	0.26	0.25
07/29-08/08	0.47	0.38
08/08-08/19	0.23	0.09
08/19-09/22	0.19	0.22
Season Average	0.34	0.36
1969		
05/19-05/27	0.11	0.45
05/27-06/17	0.32	0.38
06/17-06/26	0.31	0.08
06/26-07/02	0.29	0.30
07/02-08/22	0.42	0.42
08/22-09/05	0.27	0.41
Season Average	0.34	0.38

the ET rates for fescue from June 17 to July 2 reached a high of .63 cm/day on the southern slope, which was considerably higher than those for the northern slope.

The only times when ET rates were near maximum were immediately after periods of high rainfall, or early in the spring before the available soil moisture was depicted, usually before the soil moisture tension in the root zone reached 1 atm. With the high soil temperatures on the southern slope, high ET rapidly depleted the available soil moisture in the top 15 cm of the soil profile, resulting in water deficiency in a short period of time for such shallow-rooted plant species as bluegrass. Deeper-rooted species (bermudagrass and crownvetch) were not affected since their root systems provided access to a much larger reserve of soil water.

If irrigation could have been applied to species growing on the southern slope, much higher yields of some of the forage species could have been obtained. The higher energy levels provided by more radiation on the southern than on the northern slope could be utilized more efficiently with irrigation since low soil moisture and high temperatures, for certain diseases, were the limiting growth factors on the southern slope.

Evaporation (E) from a standard U.S. Weather Bureau pan produced a very similar pattern to that of Rn (Fig. 5). Evaporation increased with season, reached a maximum in June and July and then decreased. Evaporation was always higher on the southern than on the northern slope. However, the magnitude of the differences in E between the slopes was not as great as that for Rn. Radiometers were oriented parallel to the soil surface, but evaporation pans had to be level. Convective heat and air currents probably account for the differences in E between slopes. Air temperatures at 1 m above the soil surface were a maximum of only 2–4 C higher on the southern as compared with the northern slope. Cor-

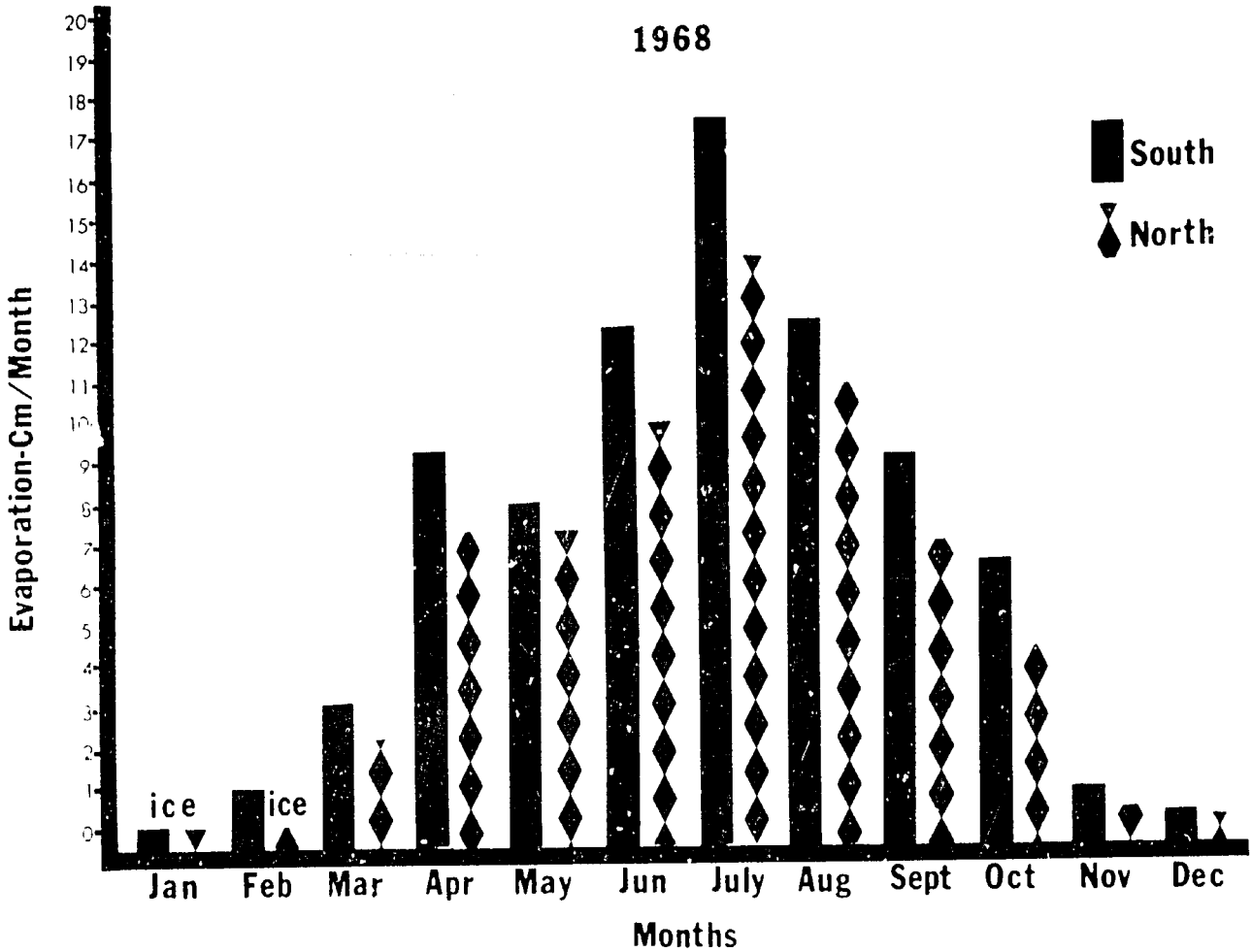

Figure 5. Monthly evaporation from a standard U.S. Weather Bureau Evaporation Pan, as affected by slope orientation in 1968.

relations ("r" = .71) were significant between E and Rn on both slopes.

We made an attempt to determine microclimatic variables responsible for E and ET during the study, using simple correlation analyses on all possible combinations of the 20 microclimate measurements and the combined totals for each variable on both slopes. The most important factor affecting evaporation was Rn with an "r" value of 0.71 on each slope (Tables 5 and 6)—0.70 when data from both slopes were combined (Table 7). Soil temperature at 2.54 cm depth in bluegrass sod was the next most important variable affecting evaporation. The correlation ("r" = 0.57) between soil temperature and E on both slopes was significant. All air and soil temperature measurements had about the same degree of correlation with E.

A simple correlation analysis resulted in low negative "r" values for the relationship between wind and E (−0.11, −0.04), indicating very little relationship between the two factors. However, this figure can be misleading, since the effect of wind on E and ET depends upon other factors, like radiation and temperature. There was a negative correlation between wind and all soil temperature measurements ("r" = −0.33, −240.48), since wind actually increases the E rate from soil surface, which lowers the soil temperature. Since Rn is measured in heat energy units, the same relationships were found between wind and Rn and between wind and temperature. Windy conditions tended to equalize temperature differences of both soil and air on both slopes. Since radiation is the main source of heat energy, highly significant correlations were found between (Rn) and all temperature measurements. This relationship between Rn and soil temperature is shown graphically in Fig. 6, which was developed by using the average maximum soil surface temperature for each month as compared with cumulative Rn for each month.

One of the purposes of making the various microclimate measurements was to develop prediction

TABLE 5. Correlation coefficients "r" for microclimate variable on southern exposure

	3	5	6	7	9	11	13	17
T max. air	0.57	0.51	0.70	0.91	0.91	0.90	0.50	0.95
Evaporation		−0.11	0.71	0.49	0.52	0.50	0.50	0.52
Wind			−0.32	−0.48	−0.47	−0.50	−0.43	−0.44
Net radiation				0.72	0.72	0.66	0.69	0.68
T. max. soil surface					0.97	0.95	0.91	0.91
T. max. 2.54 cm						0.98	0.92	0.91
T. max. 7.6 cm							0.92	0.93
T. max. 2.54 cm Fescue								0.90
T max. 2.54 cm Bl. Gr.								

TABLE 6. Correlation coefficients "r" for microclimate variable on northern exposure

	3	5	6	7	9	11	13	17
T max. air	0.57	−0.61	0.76	0.89	0.89	0.88	0.88	0.86
Evaporation		−0.04	0.71	0.56	0.57	0.56	0.50	0.55
Wind			−0.37	−0.50	−0.51	−0.50	−0.54	−0.52
Net radiation				0.78	0.80	0.78	0.71	0.74
T. max. soil surface					0.95	0.91	0.92	0.92
T. max. 2.54 cm						0.95	0.92	0.94
T. max. 7.6 cm							0.91	0.93
T. max. 2.54 cm Fescue								0.94
T max. 2.54 cm Bl. Gr.								

TABLE 7. Correlation coefficients "r" for microclimate variable on north-south slopes combined

	3	5	6	7	9	11	13	17
T max. air	0.55	−0.58	0.73	0.88	0.68	0.87	0.83	0.85
Evaporation		−0.05	0.70	0.53	0.54	0.53	0.51	0.52
Wind			−0.33	−0.47	−0.47	−0.48	−0.44	−0.46
Net radiation				0.76	0.76	0.73	0.68	0.71
T. max. soil surface					0.96	0.92	0.91	0.92
T. max. 2.54 cm						0.95	0.92	0.93
T. max. 7.6 cm							0.91	0.93
T. max. 2.54 cm Fescue								0.92
T max. 2.54 cm Bl. Gr.								

equations for E and ET. Measurements of ET under field conditions without being able to control soil moisture are at best very poor indications of potential ET. Since E from a free water surface gives a good approximation of potential ET, the development of an equation to predict E would be very helpful in predicting water requirements of plants throughout the growing season.

We made a stepwise multiple regression analysis on 16 of the microclimate variables in an attempt to identify variables affecting E. Since all soil temperatures gave a similar correlation coefficient, we averaged all soil temperature measurements, both maximum and minimum at all soil depths, and used the average value in the multiple regression analysis. Regression equations and R^2 values are given in Table 8 for both slopes and for the average total of each measurement on both slopes. Three factors—radiation, soil temperature, and wind—accounted for slightly less than 60% of the variation making up E. Radiation alone accounted for about 46%, with soil temperature adding about 9% and wind an additional 2%. This relationship varied somewhat between exposures, with the lowest percentage of the variation in E being accounted for with the northern slope. Radiation, soil temperature, and wind accounted for about 58% of the total variation in E on the northern slope, whereas almost 61% was accounted for by these three factors on the southern slope.

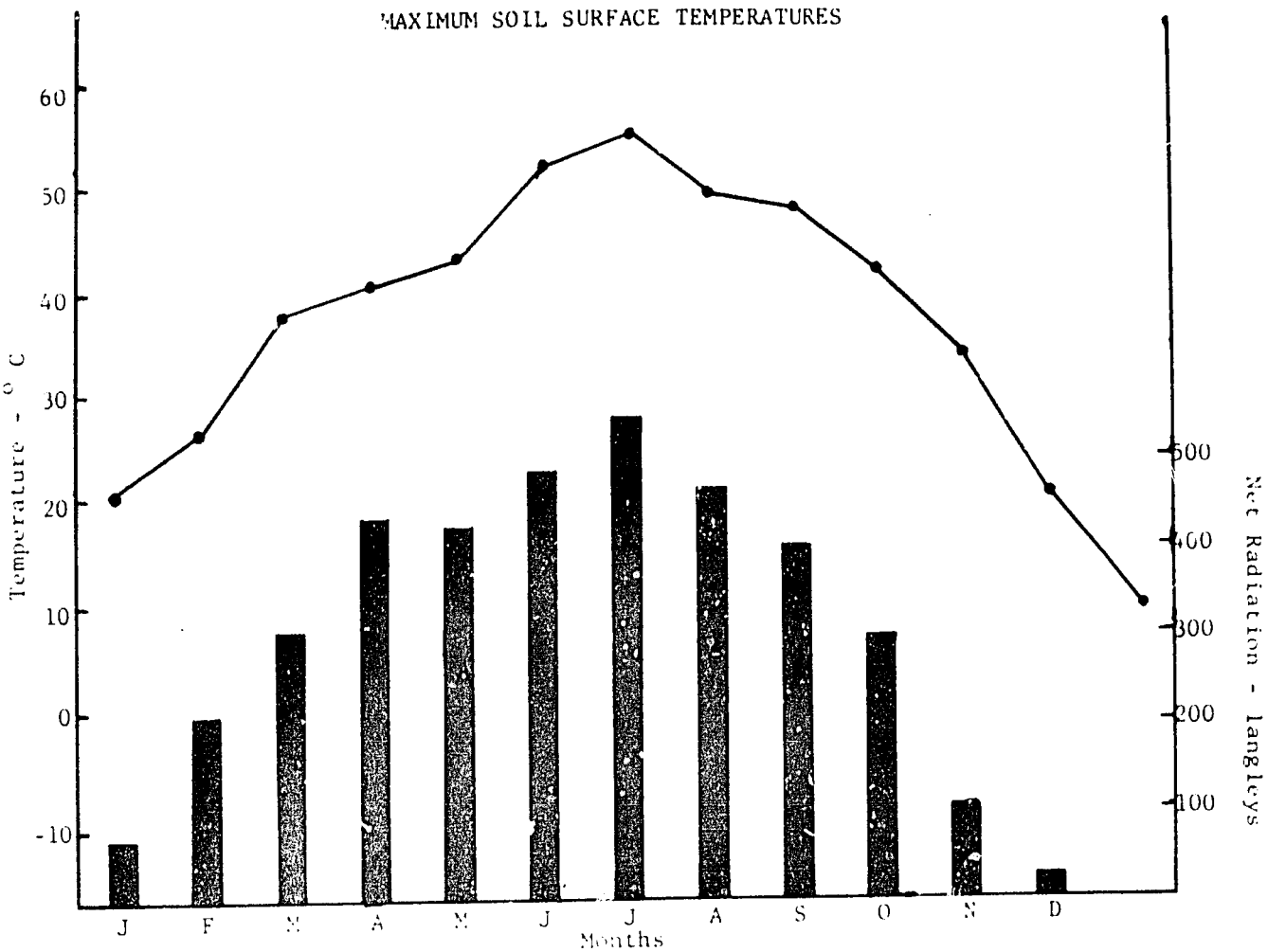

Figure 6. Relationship between net radiation (bar graph) and maximum soil surface temperatures (line graph), using averages for all slopes over a three-year period.

Curvilinear regression analyses were used on the same variables to determine if a higher percentage of the variation for E could be explained by using the square of various terms in the equation. However, no significant amount of improvement resulted.

Plant Diseases

From 1967–1970, a detailed study was made of diseases affecting the five forage species on north-south slopes (Table 9). The plant pathogens listed are not the only ones that were present; however, they were considered to be the most important. The diseases caused by *Drechslera* sp. were the most damaging on bluegrass and tall fescue, especially when grown on the southern slope. Disease problems and reduced yields from snow molds such as *Sclerotinia Trifoliorum* were encountered when crown-vetch was grown on northern slopes. The most prevalent pathogen affecting birdsfoot trefoil was *S. loti*. It may be the main limiting factor in production under high soil temperature conditions. Midland bermudagrass seemed to enjoy almost complete

TABLE 8. Regression equations and R^2 values for microclimate parameters affecting evaporation

	R^2	Increase in R^2
Southern Slope		
Evap. = 0.13504 + .00057(Wind) + .00041(Rad) + .00256(Soil T)		
Radiation	0.4984	0.4984
Soil temp	0.5891	0.0907
Wind	0.6067	0.0177
Northern Slope		
Evap. = 0.13087 + .00102(Wind) + .00034(Rad) + .00256(Soil T)		
Radiation	0.4481	0.4481
Soil temp	0.5364	0.0883
Wind	0.5779	0.0415
Both Slopes		
Evap. = 0.11227 + .00061(Wind) + .00037(Rad) + .00231(Soil T)		
Radiation	0.4582	0.4582
Soil temp	0.5496	0.0915
Wind	0.5683	0.0186

TABLE 9. Effect of slope orientation on disease incidence of five forage species

Date	Disease	Plant Species	Amount of plant damage: Southern slope (%)	Amount of plant damage: Northern Slope (%)
05-05-67	*D. vagans*[a]	Bluegrass	10	1
	D. dictyoides	Fescue	15	2
	S. trifoliorum	Crownvetch	0	10[b]
05-12-67	*S. loti*	Birdsfoot trefoil	12	2
	S. trifoliorum	Crownvetch	0	12
	D. vagans	Bluegrass	20	14
07-13-67	*D. vagans*	Bluegrass	50	16
03-15-68	*S. trifoliorum*	Crownvetch	0	75[b]
04-10-68	*S. trifoliorum*	Crownvetch	0	75[b]
	P. poae-sudeticea	Bluegrass	4	>1
	D. vagans	Bluegrass	5	1
	D. dictyoides	Fescue	3	1
04-17-68	*S. trifoliorum*	Crownvetch	0	80[b]
	D. vagans	Bluegrass	8	2
	D. dictyoides	Fescue	5	<1
	U. striiformis	Bluegrass	4	0
	S. loti	Birdsfoot trefoil	1	0
05-06-68	*D. vagans*	Bluegrass	12	6
	U. striiformis	Bluegrass	4	Trace
	D. dictyoides	Fescue	3	1
	S. loti	Birdsfoot trefoil	2	Trace
	S. trifoliorum	Birdsfoot trefoil	0	Trace
	S. trifoliorum	Crownvetch	0	10[b]
05-29-68	*D. dictyoides*	Fescue	7	5
	S. trifoliorum	Crownvetch	0	10[b]
	S. trifoliorum	Birdsfoot trefoil	0	Trace
	S. loti	Birdsfoot trefoil	20	2
	D. vagans	Bluegrass	20	5
08-12-68	*H. species*	Bermudagrass	Trace	0
	D. vagans	Bluegrass	50	3
	U. striiformis	Bluegrass	2	Trace
	D. dictyoides	Fescue	4	2
	S. trifoliorum	Crownvetch	0	Trace
	S. loti	Birdsfoot trefoil	70	10
03-20-69	*D. vagans*	Bluegrass	0	0
	S. trifoliorum	Crownvetch	0	Trace
	D. dictyoides	Fescue	1	0
05-05-69	*D. vagans*	Bluegrass	15	<1
	D. dictyoides	Fescue	8	1
	S. trifoliorum	Crownvetch	0	25
	S. loti	Birdsfoot trefoil	2	Trace
05-28-69	*D. vagans*	Bluegrass	20	<1
	D. dictyoides	Fescue	5	1
	S. trifoliorum	Crownvetch	0	20
	S. loti	Birdsfoot trefoil	15	2
	S. trifoliorum	Birdsfoot trefoil	0	Trace
07-01-69	*D. vagans*	Bluegrass	65	5
	D. dictyoides		20	5
	S. loti		30	4
04-05-70	*D. vagans*	Bluegrass	2	0
	D. dictyoides	Fescue	2	0
	S. trifoliorum	Crownvetch	0	4
05-04-70	*D. vagans*	Bluegrass	15	<1
	D. dictyoides	Fescue	5	2
	S. loti	Birdsfoot trefoil	5	<1
	S. trifoliorum	Crownvetch	0	25

TABLE 9. (continued)

Date	Disease	Plant Species	Amount of Plant Damage: Southern Slope (%)	Amount of Plant Damage: Northern Slope (%)
05-28-70	*D. vagans*	Bluegrass	15	2
	D. dictyoides	Fescue	5	2
	S. trifoliorum	Crownvetch	0	25
	S. loti	Birdsfoot trefoil	15	5

[a]*D. Vagans* = *Drechslera vagans* (Drechs) Shoem; *D. Dictyoides* = *Drechslera dictoides* (Drechs); *S. trifoliorum* = *Sclerotinia trifoliorum*; *S. loti* = *Stomphylium loti*; *P. poae-sudeticea* = *Puccinia poae-sudeticae* (West) Jorst.

[b]Based on percent of ground cover affected. Plant damage represents average values from four replications.

freedom of major diseases affecting other species. No major diseases were found on this species on either slope.

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DISCUSSION

Chairman Munro. In one point of my life I went under a period of indoctrination in New Zealand. One of the main themes was the importance of slope and aspect in pasture growth, and you've given us a very brief explanation of the details as to why this is so important.

P. Trew (Virginia, USA). Based on the data you have shown us or data that you have, what advice would you give to the cattleman that's producing grass out here?

Bennett. I think the farmer will usually know his situation. A lot of times he knows what will grow in a different field or pasture exposure on his farm better than anyone else. In these studies we were trying to show the tremendous differences in microclimate that can exist in a short distance in hill land. I think there is no question, that at the elevation where measurements were made, we certainly would recommend different species for different exposures, mainly because the farmer can make better use of his fertilizers by putting an adapted species on each exposure. We wouldn't recommend Midland Bermudagrass on a northern exposure but it is highly productive under the climatic conditions of a southern exposure. The opposite is true with bluegrass. Bluegrass is better adapted to the northern exposure

at this elevation. Now there is one point I would like to make here; as you go up in elevation, this situation may completely reverse and bluegrass would be adapted to a southern exposure.

Unidentified. In advising farmers in the management of different aspects and slopes, would you advise the separation of these areas by fencing in order to get the maximum out of it?

Bennett. Where it is economically possible, I would certainly recommend that they be separated by fencing and treated differently; that is, in terms of fertilization, time of year that they would be grazed, and managed differently. Sometimes the old cows will do this for the farmer if they have a choice. Early in the spring they'll go to the warmer conditions on the southern exposure, not only because it is warmer, but because this is where growth starts first and where they're getting something to eat. In the middle of the summer they will go to the northern exposure where temperatures are cooler and the quality of the forage is better.

T. Taylor (Kentucky, USA). I have just one question. I have not seen this data covered elsewhere. Have you published this data before?

Bennett. Yes, some is published, but not all of it.

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Soil-Plant Ecosystems in Tropical Hill Country

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In planning for the development of tropical hill lands, it is necessary to take into account the variable environmental conditions and to determine their impact on the success or failure of a particular enterprise. Hill lands are being developed for wider use for food or export crops, as well as for pasture or commercial forests. Questions which should be asked include: what factors in the hills are most important to consider in development programs; is it possible to develop techniques which can aid us in determining how best to use a tract of land; and what approaches to development should be used in situations where inexpensive and yet effective programs are required?

In Hawaii there are tens of thousands of hectares of rugged hill lands which, if planted to improved pastures, could produce significant amounts of animal products, especially beef. The most desirable of these lands lie in the high rainfall windward sides of the islands. Today many of these lands lie idle, covered with weedy secondary forests, contributing little to the welfare of the state. Also, there are many pasture lands which have become degraded through weed and brush encroachment, to the point where it is necessary to undertake improvement steps bordering on complete renovation. Many of these lands are too steep to allow mechanized clearing, weed control, or sowing. However, their potential, if developed, is great for they receive from 1 500 to over 2 500 mm of fairly well-distributed rainfall throughout the year (Plucknett, 1970).

In 1965 a series of experiments was initiated to determine the steps necessary to convert these lands from brush to pasture by using aerial applications of brush herbicides to control weeds followed by aerial sowing and fertilization (Motooka *et al.*, 1967a, 1967b, 1967c, 1968; Plucknett, 1969; Nicholls and Plucknett, 1973). Pastures were successfully developed using aerially applied herbicides, aerial sowing, and fertilization (Motooka *et al.*, 1967c). However, the pasture species showed definite patterns of stratification and distribution throughout the rugged topography which offered a variety of slopes, slope aspects, soil moisture and nutrient gradients, soil surface temperature, and soil depths. These patterns were so distinct that it was decided that more detailed studies were required to determine the effect of the environmental factors on species distribution and on potential success or failure of these species in similar hill lands. Ecological techniques were employed to study environmental factors, species distributions, and their inter-relationships (Nicholls, 1972).

METHODS AND MATERIALS

The Hawaii Agricultural Experiment Station, Wailua Research Center, on the Island of Kauai, was chosen as a main site for this work. Another site

was obtained later when a 1 500 ha section of forest reserve at Hanalei, Island of Kauai, was accidentally burned and was aerially seeded and fertilized to reduce the potential for erosion. This forest reserve site at Hanalei provided an opportunity to verify the earlier work at Wailua and also to study the hill environment and its effects on species establishment and persistence.

Experimental Sites. The original (secondary) vegetation at Wailua was dominated by false staghorn fern (*Dicranopteris linearis*) and Banks melastoma (*Melastoma malabathricum*). Less prevalent species were ohia (*Metrosideros collina* subspecies *polymorpha*), guava (*Psidium guajava*), pandanus (*Pandanus odoratissimus*), tree fern (*Sadleria spp.*), java plum (*Syzygium cumini* Druce), hau (*Hibiscus tiliaceus*), downy rosemyrtle (*Rhodomyrtus tomentosa*), lace fern (*Stenoloma chinensis*), Boston fern (*Nethrolepis exaltata*), and lantana (*Lantana camara*). The Hanalei forest reserve vegetation was composed of the same species, although ohia forest predominated at the higher elevations of the burned area.

The soils of the experimental site at the Wailua Research Center fall into the Halii soil series, a deep, well-drained, gravelly, silty clay (Typic Gibbsihumox).

The soil of the Hanalei region is classed as highly weathered, gently sloping, Kaena silty clay series rising up into rough broken land of residual material. It is classified as a Hihimanu soil (Ustoxic Humitropepts).

The elevation of the Wailua Research Center is approximately 180 m while the forest reserve lands at Hanalei lie at 120–450 m. The topography of the Center study area consists mainly of narrow, steep-sided valleys, with distinct north- and south-facing slopes, measuring up to 70%. The Hanalei area has a similar topography with similar but longer slopes. At higher elevations the slopes approach 80–85%. Both Wailua and Hanalei have a similar annual rainfall of approximately 2 300 mm, with a distinct winter maximum. The prevailing wind is a northeast trade wind with the possibility of strong southerly winds in January through March.

Pasture development was achieved by treating an elongated, steep-sided, brush-infested, 20 ha valley in 1965–66 with two aerial applications of 4.48 kg/ha of silvex, 2-(2,4,5-trichlorophenoxy) propionic acid at six-month intervals. These treatments gave about 60–70% control of the weeds and brush and caused considerable drying of the vegetation. The area was burned in 1966 to produce a good ash seedbed. Twelve pasture legume species and cultivars along with two grass species (Table 1) were aerially sown into the ash together with the fertilizer. The legume seeds with appropriate *Rhizobium* strains were pelleted with T.V.A. slag using methyl ethyl cellulose as the adhesive. Biennial applications of fertilizer were made up to June, 1970 (Table 2). After planting (October 13, 1966) a twelve-month establishment period was allowed followed by a nine-month period of continuous grazing. In June, 1969, the area was subdivided and the three sections were rotationally grazed on a three weeks on, six weeks off basis.

TABLE 1. Pasture species sown in the Wailua Research Center valley land development experiments

Species	Cultivar	Sowing rate (kg/ha)
LEGUMES		
Glycine wightii	Clarence	0.56
	Cooper	0.56
	Tinaroo	0.56
	Early flowering	0.56
Desmodium intortum	Greenleaf	0.84
Stylosanthes guyanensis	Schofield	1.12
Macroptilium atropurpureum	Siratro	0.56
Centrosema pubescens		1.12
Lotononis bainesii		0.56
Trifolium repens	N.Z. mother white clover	1.12
	N.Z. white clover	1.12
	Ladino white clover	1.12
GRASSES		
Panicum maximum var. *trichoglume*	Green-panic	2.24
Cynodon dactylon	Bermuda NK-37	2.24

Ecological and Vegetation Analysis Studies. Important phases of the research program included the verification of evident distribution patterns of certain forage and weed species; the collection of vegetation and environmental data in order to relate

TABLE 2. Fertilizer applications, Wailua Research Center valley land development experiment*

Date	Fertilizer applied	Nutrient applied (kg/ha)
October, 1966	(Aerial sowing) plus 224 kg triple superphosphate/ha	40P
December, 1966	224 kg (18-46-0)/ha	40N, 44P
June, 1968	224 kg (7-30-20)/ha	15N, 29P, 35K
June, 1970	225 kg (7-30-20)/ha	15N, 29P, 35K

*All fertilizers were aerially applied.

these patterns of growth to gradients of environmental parameters; and the study of sward dynamics and productivity, identifying weeds most reliably indicating sward degeneration.

Mapping of species distribution patterns was facilitated by the use of data collected from belt transects and aerial and ground photography.

Further field observations and data collecting took place on adjacent, freshly burnt hill lands of similar topographic and climatic nature. Species distribution patterns and some soil profiles associated with these patterns were also studied at the Hanalei forest reserve.

Sampling Transects. The valley at Wailua provided slopes with approximate north and south aspects. The transects were located by randomly selecting an azimuth for the first transect and then running the others parallel at equal distances apart, using a surveyor's transit.

On each transect five steel posts were located on each slope in such a manner that the first post on top of the south-facing slope was at the same elevation as the first post on top of the north-facing slope and so on down the two slopes. A transit was used to set ten sites on each of the four transects. These 40 sampling sites were used to gather data on soil physical and chemical factors, soil surface temperature, forage productivity, and species dynamics. Nine other transects were established to measure vegetation dynamics.

A "belt" transect was used to measure species distribution and dynamics. This belt method of sampling is made up of a "rolling" quadrat, 1 m square, along each transect. At each quadrat position along the transect, presence and absence data were recorded for each weed and improved species. This provided a means of mapping the distribution patterns of particular species at different locations along each transect. Thousands of individual quadrats were taken to verify the vegetation patterns observed.

Soil and Plant Analyses. Soil moisture, pH, total soil N, extractable P, exchangeable K, Ca, Mg, and Mn, and water extractable Si were measured along valley transects and within the drip ring of dead trees. Soils were sampled to a depth of 20 cm. Standard methods were used (Nicholls, 1972). Plant analyses included: crude protein, P, K, Ca, Mg, Mn, Zn, and Fe.

RESULTS AND DISCUSSION

The Hill Environment

Certain soil and climatic factors were measured in this study. This turned out to be fortuitous, for both of these environmental factors varied widely and appeared to be important in influencing species distribution. Detailed descriptions of the factors are beyond the scope of this paper, but some of the more interesting trends will be reviewed here.

Topography. The percent slope at each of the 40 sampling sites in the Wailua site ranged from 0 to 75% across the valley (along the transects), 0 to 60% at right angles to the transects. The south-facing slope was steeper than the north-facing slope, the former averaging 56% and the latter 42%. Slope aspect influenced angle, duration, intensity of the sun's rays, and other factors such as humidity and the cooling effect of wind. Even though there were evident species distribution patterns within a particular slope, there were no evident differences in species composition between slopes of different aspects.

Air Temperature at the Ground Surface. In order to measure soil temperature at the ground surface from one position on the slope to the next and from one slope to the other at different times of the day, three maximum-minimum thermometers were set up at equal intervals on one north-facing and one south-facing slope. To protect these instruments from cattle, a heavy metal case was constructed around them so that air circulation across the thermometers was possible. Temperatures were read daily for one year, recording daily maximum and minimum temperatures and the temperatures at 0800 and 1600 hours.

The south-facing slope had the highest daily temperatures at all times of the year (Fig. 1). Highest maximum temperatures on this slope occured between August and October, and the lowest occurred between November and January. There was a lower maximum temperature at the ground surface on the tops of both slopes, compared to locations farther down the slope. This could be explained by a "shearing" or cooling effect of the wind across the top of the slopes leaving relatively still, warmer air at or near the valley bottom. This could be especially significant when one considers that the northeast trade winds blow almost constantly across these hill lands.

There was little fluctuation in daily minimum temperatures from one location to the next across the valley. This was to be expected since the sun's orientation has no influence on minimum temperatures which occur during the night hours. Lowest daily minimum temperatures occurred in the period Febuary–April and the highest during August–October.

Morning temperatures were generally higher on north-facing slopes (Fig. 2). Differing from afternoon and daily maximum temperatures, morning temperatures were highest on the tops of both slopes. This can be explained by two factors. First, in the morning much of the valley bottoms and lower slopes are still in shadow and therefore much cooler. Second,

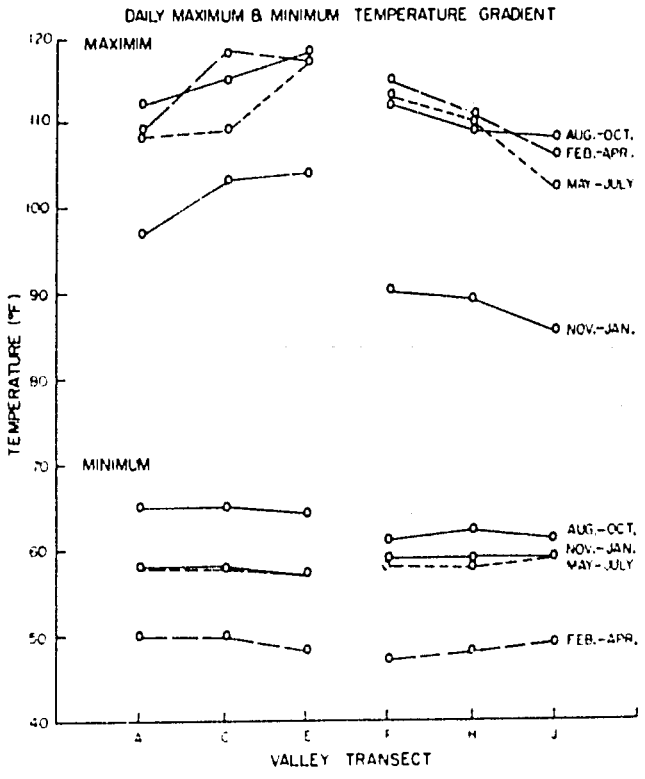

Figure 1. Gradients of the daily maximum and minimum temperatures at the ground surface along the valley transect at different periods of the year. A is at the top of the south-facing slope and J at the top of the north-facing slope.

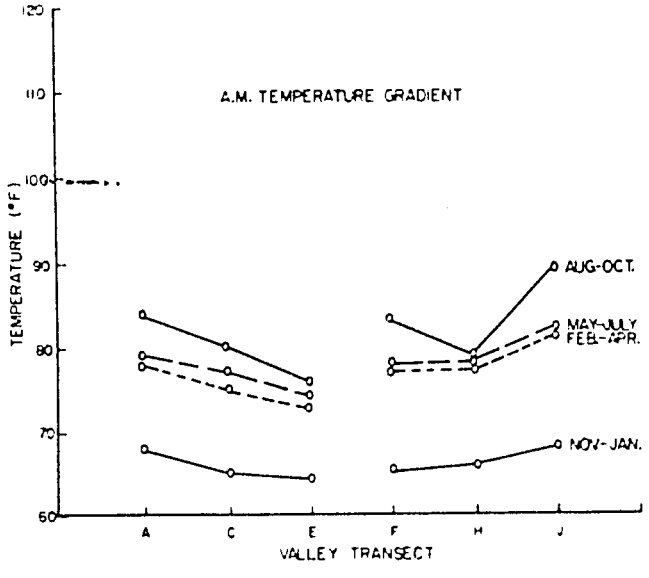

Figure 2. Gradients of morning temperature (0800 hours) at the ground surface along the valley transect at different periods of the year. A is at the top of the south-facing slope and J is at the top of the north-facing slope.

the wind influence does not begin until early afternoon, explaining why there is no cooling effect on the top of the ridges in early morning.

Afternoon ground surface temperatures were reversed from those of morning (Fig. 3). Here highest values occurred on north-facing slopes, but with the cooling effect of the afternoon wind, temperatures on the tops of slopes were lower than those toward the valley bottom.

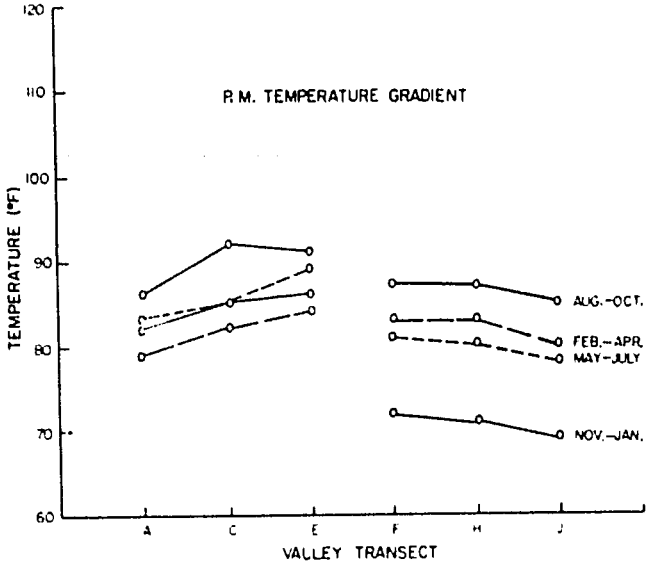

Figure 3. Gradients of afternoon temperature (1600 hours) at the ground surface along the valley transect at different periods of the year. A is at the top of the south-facing slope and J is at the top of the north-facing slope.

Soil Factors: Soil Profile. Generally, the thickness of the A-horizon increased down the slope (Fig. 4). If we take the A_1 horizon as being that shallow layer, high in organic material, overlying the A_2

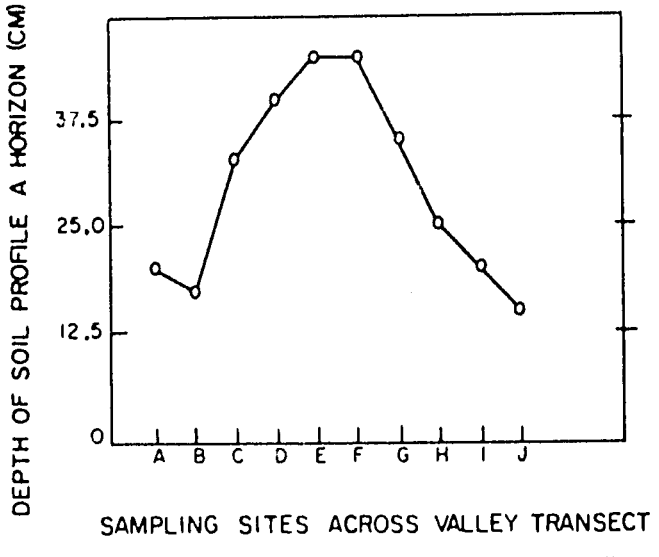

Figure 4. Gradients of depth of soil A-horizon along a valley transect. A is at the top of the south-facing slope and J is at the top of the north-facing slope.

horizon, the thickness of the latter varied from as shallow as 12 cm at the top of the slope to as much as 60 cm at locations lower on the slopes. Generally, the amount of large, weathered, rock-like aggregates (saprolite) was greater in profiles near the top of slopes and on ridgetops, but was less toward the valley bottom.

Locations toward the middle and lower areas of the slope, with deeper profiles of higher moisture and mineral content, were more conducive to growth of the more vigorous, fertility-responsive grasses and legumes. On the other hand, shallow soil profiles on ridgetops, with lower soil moisture and shallower rooting zone, are less conducive to growth of these plants. Species with lower fertility requirements were able to survive and compete on the shallow soils on the ridgetops.

Soil Moisture. There was a soil moisture gradient along all valley transects sampled. Soil moisture was highest near the valley bottom and lowest on ridgetops and upper slopes. This trend was consistent and independent of the time of year. The dominant factor causing this was undoubtedly the drainage pattern of both surface and ground water down the slope. Also, as was seen from soil surface temperature and soil profile measurements, the drying influence of wind and the lower water storage capacity of the shallower surface horizon of profiles up the slope probably contributed to these soil water trends. Higher humidity and still conditions at valley bottom also may be a factor in reducing evapotranspiration and in maintaining a higher soil moisture content.

Soil nitrogen increased down the slope, following trends of other important plant growth factors—soil moisture and nutrients—and providing conditions more suitable for plant growth and higher soil micro-organism activity. Valley bottoms also supported much stronger legume growth which would enhance the soil N supply.

Extractable Soil Phosphorus. There was little variation in P values along the valley transects. As would be expected in this soil (Typic Gibbsi-humox) P levels were quite low (12–14 ppm P).

Exchangeable soil calcium generally was higher toward the bottom of the slopes. Highest values recorded were 2 to 3 meq/100 g soil near the valley bottom and the lowest was 0.1 meq/100 g at the top of the slope.

Exchangeable soil magnesium increased significantly down the slope. Near the top of the slopes mean values were about 0.5 meq/100 g soil, whereas sites on lower slopes had a mean value of 1.5 meq/100 g. Highest recorded was 2.8 m.e./100 g, near the valley bottom.

Exchangeable soil manganese increased down the slope; the low mean was 1 ppm at top of slopes, while the high mean value was 2.5–3 mg/kg toward the valley bottom. Actual lowest and highest values were 0.3 mg/kg and 5 mg/kg, respectively.

Exchangeable soil potassium was extremely variable. Values were well below the range of 0.2 to 0.8 meq/100 g soil recorded for soils of the same series. Until 1970–71 no K was included in the fertilizer mix and *Desmodium intortum* exhibited typical K deficiency symptoms. Addition of K in the fertilizer removed this symptom but at the end of the 1971 wet season the deficiency appeared again.

Potassium was found to increase somewhat further down the slope. Mean exchangeable K was 0.06 meq/100 g.

Soil pH. There was a general decrease in pH toward the valley bottom. The mean values were 5.1 and 4.6 on slope tops and the valley bottoms, respectively.

Soil Measurements in the Tree Drip Ring. Early in the study it was apparent that some legumes, notably *Glycine wightii*, grew luxuriantly in the drip rings of dead trees. Special studies were therefore designed to attempt to understand these striking growth patterns.

Soil moisture surprisingly decreased near the trunks of larger, dead trees. Transpiration losses of soil moisture through vigorous legume growth which accumulated around these trees was thought to be an explanation. However, on removal of this vegetation and after two years, the same moisture gradient was evident. It could be that drainage of soil water was enhanced by root channels, especially those of larger roots originating from the base of the trunk.

Total soil nitrogen did not show a gradient as marked as other soil nutrients measured. The mean value of 0.5 to 0.6% N was higher than that measured along the valley transects. This difference may be accounted for by the greater leaf fall and organic matter accumulation in the drip ring, as well as by the vigorous legume growth which resulted within the drip rings of larger trees.

Extractable soil phosphorus increased toward the main trunk. Overall, P was higher inside the drip ring than in transect sites away from the influence of the trees (12–14 mg P/kg outside; 12–22 mg P/kg inside the tree drip ring).

Exchangeable soil potassium was much higher inside the tree drip rings (0.1–0.15 meq/100 g) than outside (0.03 meq). Also, K values increased significantly toward the trunk. Greater accumulation of bark and leaf ash as well as natural leaf drop would result near the trunk.

Exchangeable calcium increased near the trunk. There was a great difference again in mean Ca of soil in the drip ring (4–8 meq/100 g) as compared to outside (0.25–0.75 meq/100 g).

Exchangeable magnesium followed the same pattern as Ca. Values inside the drip ring were 6–10 meq/100 g as compared to 0.75–1.5 meq/100 g outside.

RELATIONSHIP BETWEEN SPECIES DISTRIBUTION AND ENVIRONMENTAL FACTORS

Multiple regression analyses were used to rank environmental factors in order of their importance in influencing a particular vegetation pattern.

Not all legumes and grasses studied will be discussed here. However, the distribution of some species, both improved pasture species as well as weeds, will be discussed as examples of the interactions observed and measured.

After several years of grazing, only a few pasture plants—*Stylosanthes guyanensis*, *Desmodium intortum*, and *Panicum maximum*—were contributing a significant amount of forage or were present over larger areas of the pasture. Also, some weeds and weed associations covered large areas of the pasture. These plants, plus a few pasture plants which showed unique or noteworthy distribution patterns or environmental responses, will be discussed.

Stylosanthes guyanensis (Stylo). Stylo grew predominantly on ridgetops and upper slopes where soil fertility and moisture were very low (Fig. 5).

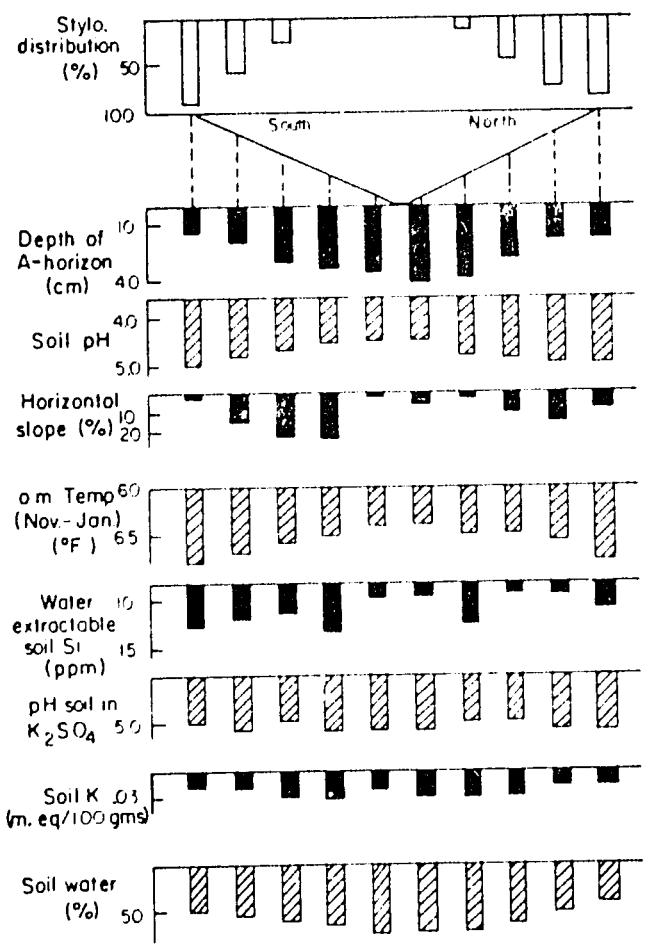

Figure 5. The distribution of *Stylosanthes guyanensis* as influenced by environmental factors.

Soil depth and soil pH were the most influential factors in describing its distribution pattern. With an increase in soil depth and a more favorable nutrient status down the slope, there was a corresponding decrease in stylo as a sward component.

Desmodium intortum (intortum). Intortum distribution was just the reverse of stylo (Figure 6). It grew best and most vigorously on lower slopes and in the valley bottoms, but seldom was found on upper slopes or on ridgetops. Environmental factors which appeared to exert most effect on intortum distribution were soil surface temperatures during spring (February–April), total soil nitrogen, exchangeable soil calcium, and manganese. Soil moisture status was much higher near the valley bottoms, and this undoubtedly had a strong effect on intortum growth and distribution.

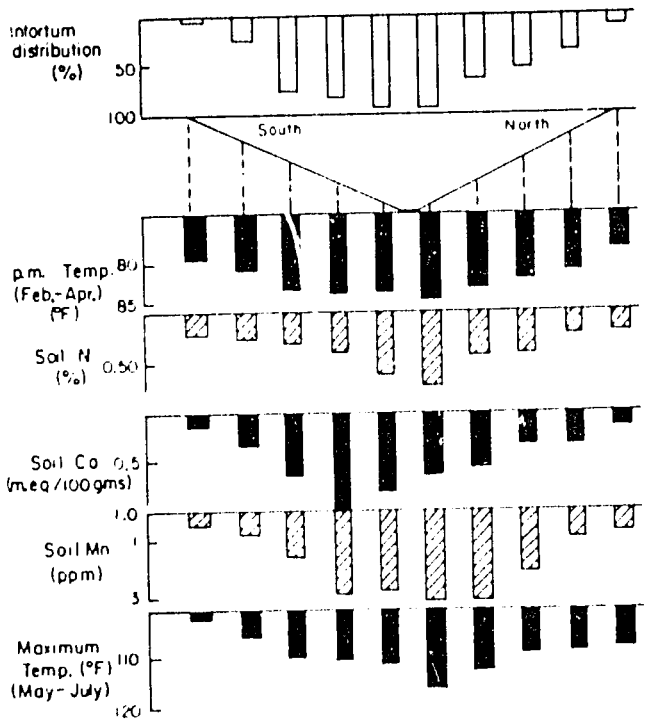

Figure 6. The distribution of *Desmodium intortum* as influenced by environmental factors.

Panicum maximum var *trichoglume* (green panic). The distribution of green panic was much like that of intortum, with a heavy concentration of the grass on lower slopes and the valley bottom (Fig. 7). The combination of green panic and intortum provided a competitive barrier to the invasion of weeds. This desirable balance occurred only at locations lower down the slopes where conditions for vigorous growth were more favorable for these improved species. Soil moisture, soil nitrogen, and soil manganese reliably explained the pattern of green panic distribution.

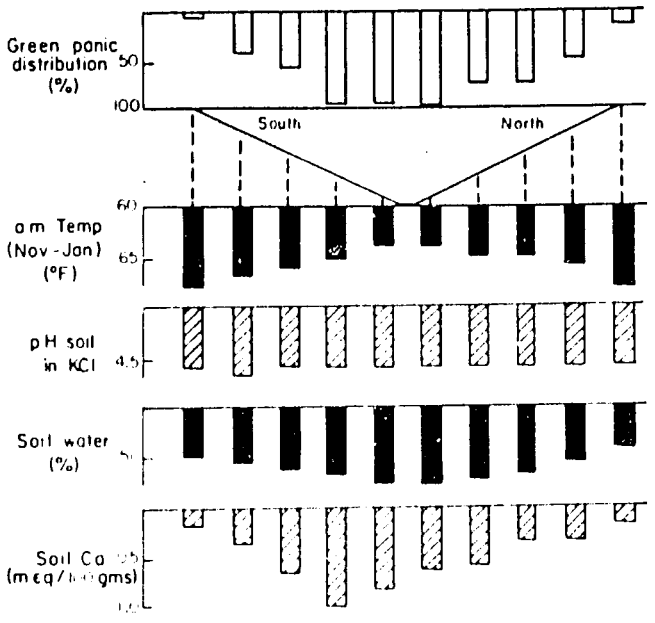

Figure 7. The distribution of *Panicum maximum* (var. *trichoglume*) as influenced by environmental factors.

Glycine wightii (glycine). Glycine grew best in the drip rings of dead trees where it quickly climbed to the tree tops and formed dense tent-like canopies of luxuriant growth. Glycine is known for its high soil fertility requirement and the tree drip rings were found to have significantly higher levels of soil nutrients than surrounding areas not affected by trees.

Although glycine was not often found in early vegetation analyses, it did increase later in valley bottoms. This may be due to its ability to grow on dead trees and to produce and disseminate seed, thus increasing the amount of glycine in the pasture.

Paspalum conjugatum/Setaria geniculata. These two weedy grasses are frequently found on shallow soils of poor fertility, as they were in these hill lands. Soil depth and soil moisture were found to be most important in influencing their distribution. However, the shallow soils on which they were found are also highly infertile.

Stylo/Paspalum/Setaria Association. There was a strong positive correlation between distribution of stylo and the weedy grass associations. Environmental factors most closely associated with the distribution pattern of this ridgetop community were soil depth, soil magnesium, and soil slope.

Stylo/Weed Species Association. The distribution of *Lantana camara, Melastoma malabathricum, Elephantopus mollis,* and *Stachytarpheta urticaefolia* generally followed that of stylo, that is, towards the tops of the slopes and ridges. On ridgetops, the environmental factors which influenced plant growth included soil depth, soil pH, and soil moisture. Ridgetops—with a high proportion of bare ground and lack of vigorous, competitive forage species—provided ideal conditions for invasion by weeds. Relationships between distribution patterns of individual weed species and environmental factors have been discussed previously (Nicholls and Plucknett, 1973).

USEFULNESS OF MULTIPLE REGRESSION ANALYSIS IN THESE STUDIES

The need for a system of analysis to extract meaningful conclusions from such a mass of data is evident. However, the inclusion of so many interrelated environmental factors can lead to conclusions which over-emphasize individual components at the expense of other highly correlated parameters. By logically manipulating the environmental parameters, their actual influence on a certain species or species association can be better evaluated. Even though it was impossible to study the influence of all factors of the environment, we were able to extract groups of factors which explained a significant portion of the variation in distribution of particular species or species community response.

For the future, the more important environmental factors that should be studied in detail include: soil nutrient and moisture components, soil pH, soil profile characteristics, position on the slope, and slope aspect.

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DISCUSSION

J. Baylor (Pennsylvania, USA). One of the comments you made was relative to seed availability. We used seeds that were available in the Bahama Project and a few other locations and we had some problems. There is a need to find some method by which we can have better availability of the tropical seeds and a more consistent supply. I think that the record of the Conference should note that if you're going to use the hill lands in the tropics, you're going to have to have available a more consistent supply of the species and varieties of tropical legumes and grasses that are needed.

Plucknett. I agree, but it is not the seed supplier's fault. Because of the economic situation, the cattle market goes up and people get interested in developing tropical pastures and then the market goes down and interest fades, so there's a cyclical problem which causes dislocations in the seed industry. We need a variety of species. We cannot rely on only one or two; we have too many microclimates to satisfy. One of the reasons I think we haven't been successful in many cases is that we haven't been able to get the right seed in the right place.

C. Roberts (New South Wales, Australia). I would appeal to everybody who's interested in developing a project of this kind to try to let the seed suppliers know as far as possible in advance because every year there are large quantities of this seed going to waste in Australia. They're not harvested because we can't forecast demand and it's too expensive to hold just in the hope, because it will deteriorate in storage. If you can give us six months notice of your requirements, we would be able to make sure that we would meet your full requirements with the best possible price. If you come in at the last minute, you're likely to get second-rate seed at the highest possible price, or possibly no seed at all.

As an illustration of the dangers of generalizing, which unfortunately is necessary in the short time available, I mentioned the advantages of early grazing, and this is entirely a matter of the species you're using. Don was using green panic, which is a very easy grass to manage—it's not very aggressive whereas the example I gave the other day was Setaria, which is most aggressive—a tall-growing, fast-growing species. Early grazing is important in that case. In Don's case it wasn't important—it was much more important to let the legumes smother the weeds. This is the whole art of managing these things, where you've got these complex mixtures, to understand the growth characteristics of the species you're using and adjust your management practices according to the species.

Plucknett. I agree. One comment that I should have made in the paper: In the area where we established this pasture, the kind of legume growth we obtained had not been possible in the past. We had had nothing but trouble getting pasture legumes into this kind of area before, and we had to go to great efforts with fertilizer trials and other management steps to get legume stands and persistence. In this instance we have had no problems with persistence or growth, and we have never put on the heavy levels of fertilizer like we thought we had to in the past. I think that primarily it was because we got good establishment. What we had been dealing with before—lack of persistence because of poor establishment and poor growth—was really related to establishment problems.

Baylor. The comments I made were in defense of the seedmen's position and not in criticism of them.

A. Tanis (Haiti). As to the question of available seed supply, I would like to add this. All of us know that research is very expensive and I would appreciate it if we could increase the exchange of scientific information between areas where the climatic condition is almost the same. That would help to solve this problem.

Plucknett. I agree. One of the things I pushed when I was working with AID was to try to get a soil classification for all of the major research stations in the tropics. If experimental stations were classified under one soil classification system, then we could see if we could make any correlations based on that. We talk about agro-climatic zones or ecological analogs; this would help us to find them. We could start that way by having the major research stations in the tropics compare soil classification done under one system. I agree, we need to exchange information.

H. Massey (Kentucky, USA). I was interested in your tree ring effect and the nutrient recycling that it implied. Have you thought about the longterm implications of this? Do you think that some of these perennial legumes will do this same sort of recycling or that perhaps your idea of leaving half or so of the area in trees might be good over the long-run provided you switch back and forth and later kill out an area of trees and use that?

Plucknett. I think that there's no question that some of these deeper-rooting species are going to do some nutrient recycling. These lands, even though they are infertile in the surface soil, do have more bases at depth and it's obvious that a deep-rooted species can bring these up with time. I think that the question of the role of trees is a very good one. It has been my experience that we have over-cleared forest lands in the tropics in many situations. As a matter of fact, I could show you one area where two ranches adjacent on the Island of Hawaii have over-cleared—one cleared almost entirely and the other cleared

to the point where they had 40 or so trees to the hectare, and the difference in precipitation is nearly a thousand mm. The one with trees actually gets more, much more, precipitation than the one without trees although they are adjacent properties in the same areas. This is water harvesting from fog drip. I think the same is true in nutrient recycling. I'm not at all sure that we aren't over-clearing the tropics and I think we probably ought to leave more trees or encourage the growth of certain trees that cycle more nutrients than others. I'm certainly against heavy clearing of many tropical areas until we have a better understanding of what the impact will be. Many small farmers in the tropics leave tree species in their fields. Sometimes they do this because they are trying to mimic the rain forest. I think there is a lot of sense in mimicking the rain forest, particularly in the infertile areas.

83.
Understanding Hill Land Ecology in New Zealand As a Basis for Management

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THE EVOLUTION BY FIRE OF THE GRASSLAND ESTATE

The hill lands of New Zealand, extending from sea level to more than 2000 m in middle latitudes, form the largest component of the pastorally used land of the country. In the North Island they have been induced in the last hundred years from evergreen forest, principally below 700 m, or from seral communities of scrub and fern succeeding volcanic ash showers. This process of conversion of "bush into grass" has been the ecologic and economic mainspring of European civilization in New Zealand. In the South Island, however, the "bush into grass" process has been less extensive. Instead, pastoral use in the last 120 years has taken over tussock grasslands, shrublands, and herbfields that occupied the mountains above natural timberline, as well as the more extensive tussock grasslands in lowland, montane, and lower sub-alpine zones that succeeded the destruction of forest and shrublands in early Polynesian times, generally 1000 to 700 years ago.

Most grasslands in New Zealand have, therefore, been derived from forest or open shrublands. Most of the grasslands in the moist and milder zones have been made by European man by felling and burning forest and by grass sowing, principally for close settlement during the fifty years from 1870. In the zones subject to severe drought or to more severe winters, an already deforested landscape of tussock grasses, scrub, phormium, and open parkland was burnt from the 1850's for ease of passage and was quickly occupied in extensive sheep or cattle runs.

Sown Grassland Under Closer Settlement

Some of this land, especially on the Cantebury Plains, was converted to arable farming late in the 19th century. Much of it in eastern parts of both islands was converted to more intensive livestock farming with closer settlement over the same period. All such closely settled land, whether directly cleared from forest or deforested earlier in Polynesian times, came under the influence of the new phosphatic fertilizer technology, slowly at first from 1910. For another 30 years from that date, hill country had little share in the increasing national application of superphosphate on pastures. Recovery of woody plants on land recently deforested had to be fought with steel slasher and livestock. Pastures decreased in vigor and density as soil fertility from the ashes of forest fires declined. As tree and shrub root nets decayed and swards deteriorated, slope instability became common. As technology was developed for aerial application of fertilizer from the late 1940's, the deterioration of all but the worst terrain was arrested. As is illustrated in the papers of Brougham, Suckling, and Hight in these *Proceedings*, high levels of production are often now being achieved.

The "Native" Country in Extensive Pastoral Use

While most hill grasslands had gone the way of closer settlement, approximately five million hectares remained in extensive pastoral occupation, principally as tussock grasslands. Three million ha constituted the pastoral "high country" in regions

subject to snow where some 300 pastoral "runs" traditionally produced fine wool from public lands leased solely for that purpose. Some two million ha constituted the "native hill country," principally tussock grasslands but including also danthonia tufted sward grasslands, fernlands, and shrublands, generally in zones of lower snow risk in eastern parts of both islands. This land has traditionally produced both wool and "store-condition" sheep and, often, cattle. It has been farmed somewhat less extensively than the "high country" and has been held as farmland under renewable lease or as freehold.

Fertilizer technology was not widely introduced to any of this "native" hill and high country until the 1950's. Hitherto, its management had been by periodic burning, initially as frequently as once in three years, generally less frequently by the 1940's and comparatively rarely in the last two decades. Grazing had been seasonal set stocking with minimal herding within natural or fenced boundaries on blocks of several hundreds or even thousands of ha. Carrying capacities were one sheep per ha on the best of the foothill runs, one sheep to two ha in the better high country, one sheep to five ha on the rougher, steep high country of the mountain gorges. Legumes were few, sparse, and unproductive. Although exotic grasses had become established up to about 1 000 m altitude among the tussocks, depletion was conspicuous in the highest zones and in the driest zones at low altitude. Erosion by frost action or needle ice was widespread on depleted ground in the uplands with spectacular slope and channel instability in those mountains formed of greywacke and argillite. In the driest zones at lower altitudes, vegetation depletion had been followed by wind erosion with locally prominent rilling and gullying.

Convergence and Divergence in Cultural Evolution

This summary of the historical evolution of New Zealand grassland systems indicates some common elements of forest origins but also some variety in the history of deforestation and some geographic differences in settlement pattern and pastoral resources. Also evident are common threads of hill pasture decline but some variety in stage of deterioration reached in regard to carrying capacity and system stability. Last of all, there are common elements in the pattern of rebuilding and a great variation in level of achievement in what is here called "the grassland development transition," the cultural transition from grasslands of low productivity and often poor soil fertility to grasslands of high productivity and soils of high fertility.

ECOLOGY AFFECTING CHOICE AMONG MANAGEMENT OPTIONS

Other papers in these *Proceedings* describe how grassland has been improved on hill country in various parts of New Zealand. My intention is to illustrate the interaction of four cardinal ecologic relationships in these hill land pasture systems as they have evolved, showing the varying significance of each to the principal management options which seem open. These options for management seem to me to be:

1.
(a) to abandon pastoral farming in favor of some other use or no use at all *or*
(b) to combine pastoral farming with some other use *or*
(c) to continue pastoral farming as an exclusive or at least dominant use;

2.
If pastoral farming is to be continued in some way, then:
(a) to manage the existing grassland resources *or*
(b) to develop the existing grassland resources;

3.
If grassland resources are to be developed, the development is to be:
(a) with what principles and practices? *and*
(b) to what level of achievement? *and*
(c) to fulfill what policy?

My thesis is, therefore, that understanding hill land ecology helps explain the behavior of these grasslands under pastoral use and helps guide future management. Hill land ecology is not seen as a narrow and perhaps elegant conceit of soil, plants, and animals but as the science of understanding hill land use systems which include man as manager. They are not closed systems but are linked in complex ways with other agrobiosystems.

In my illustrations I shall refer principally to the tussock grasslands of New Zealand where, for the last 20 years, I have been able to study the recapitulation of the whole history of New Zealand hill lands which I summarized at the outset. I shall deal with salient interactions among four ecologic regimes in hill lands: those involving energy, water, minerals, and animal behaviour.

Energy Regimes and Their Implications for Management

Primary productivity in New Zealand hill country is favored by generally satisfactory solar radiation. As shown by Coulter (1975), average incoming solar radiation at the surface varies little with latitude in mid-summer, reaching a maximum in excess of

500 ly/day for December in northern and eastern coastal districts of the North Island and in some inland areas of the South Island. In mid-winter, incoming radiation ranges from below 100 ly/day in the extreme south to more than 200 ly/day in the extreme north. Net radiation has been little studied but clearly varies much more than incoming radiation. In humid, improved grasslands reflectivity may be 20-30%. In drier tussock grassland areas, it may be 30-40% (Coulter, 1975). Altitude and aspect have significant effects on radiation regimes. Bliss and Mark (1974) have shown that daily average incoming radiation may approach 600 ly/day in summer at nearly 1400 m on the rolling summi Rock and Pillar Range, Central Otago, at latitude 45° S. Frequent frosts throughout the season lower net radiation. Steep topography and high relief through much of the New Zealand hills and mountains result in marked differences in radiation between northern sunny aspects and southern shady aspects.

Temperatures are greatly affected by altitude. Most of the climatalogic stations, like the people but unlike the hill landscapes, are situated below 500 m above sea level. Intermountain basins show much greater seasonal range and mean daily range between maximum and minimum than do coastal places (Coulter, 1975; O'Connor, 1976a). Higher elevations are characterized by low maxima in winter but low minima persist throughout the year. Perhaps because of the insular macroclimate, insolation greatly affects air temperature close to the ground. Marked aspect differences occur in temperature between sunny and shady slopes (Archer, 1969). At lower altitudes these aspect differences may be especially marked in soil in early spring (Radcliffe *et al.*, 1976), but, as at higher altitudes (Archer and Collett, 1970), they may be evident through the growing season. In the dry Central Otago region the upper slopes and rolling tops of the schist block mountains receive considerably more precipitation than the 300-500 mm annually of the intermountain basins (Mark, 1965a). Similar but less striking trends of increasing precipitation with altitude are found in the moister mountains to the north.

These landform effects on energy regimes and their interaction with hydrologic regimes at different altitudes, coupled with the general windiness of the country and the intensive funnelling of winds induced by mountainous terrain, influence vegetation (Mark, 1965a, 1969). In the lower hill country, Radcliffe (1971), White *et al.* (1972) and Radcliffe *et al.* (1976) indicate the effect of aspect on pasture availability, with pasture growth often beginning earlier in spring and ceasing more abruptly in summer on the exposed northwestern slopes. In the higher mountains, Archer and Collett (1970) have indicated distinctive plant communities on sunny and shady aspects, with marked between-aspect differences in microclimates of the pastorally modified communities.

In his review of the ecology of snow tussocks, the characteristic grasses of the mountain grasslands of New Zealand, Mark (1969) indicated the relatively harsh environments throughout a five- to eight-month growing season in the mountain zones. He noted the slow growth rates of tussocks, their low productivity, and the persistence of green leaves through two or more growing seasons despite the often frequent frosts and snowfalls. In later studies with tillers of three species of *Chionochloa* in controlled environments, Mark (1975) confirmed the low net assimilation rate of *Chionochloa* tussocks indicated by Scott and associates (1966, 1970), rates generally only a fraction of those determined for herbs of sunny temperate habitats and generally substantially less than most arctic and alpine species for which net assimilation rates were known. Mark examined other features of the physiological strategy of these tussock species, revealing that, unhardened, they could assimilate at freezing point and −5° C, but that they were incapable of responding to even optimum temperature after nightly frosts for two months. In contrast, their immediate response to more favorable temperature as not affected by a single below-freezing treatment lasting five hours. The evidence seems conclusive that such subalpine and alpine species as Mark studied are well adapted with their evergreen habit and low energy demands to cool, windy environments where a balmy day of summer may be followed by bleak sub-antarctic weather, typical for island mountains in the southern seas. O'Connor and Lambrechtsen (1967), in studies with exotic grasses, likewise demonstrated that "intermediate" varieties were superior to both winter-dormant and winter-active varieties in revegetation of a sub-alpine site, just as they were found to be for pasture improvement at lower altitudes.

Clearly, the effects of relief and topography of hill lands on energy regimes affect the kind of soil and vegetation we have and the kinds of vegetation we must seek as management objectives. Tolerance of changeable weather is an essential plant attribute for New Zealand hill lands. The same edaphic and climatic selection and adaptation process that has apparently functioned in the differentiation and evolution of the genus *Chionochloa* is confidently expected to furnish New Zealand ecotypes of exotic grasses and legumes for primary revegetation work with complete fertilizers (Dunbar, 1970, 1974; Ritchie, 1972; Davis, 1975; Nordmeyer and Davis, 1976). This may lead to greater efficiency in fertilizer use in future pastures as land scars are healed. It may alternatively lead to the reinvasion of slower-growing native herbs and alpine shrubs (Dunbar *et al.*, 1977) in a restored protective mantle.

Implications of Geochemical and Animal Grazing Regimes

Recent research (Williams *et al.*, 1977a) demonstrates that *Chionochloa* snow tussock species are also well adapted in different ways to geochemical regimes. Table 1 shows that the three principal snow tussocks of the South Island pastoral country are differently related in shoot phosphorus yields to different soil P fractions determined in the modified Chang and Jackson procedures. *C. flavescens* "eastern Canterbury form" is best adapted to young soils in which calcium bound P (P_{Ca}) is characteristically abundant and from which P_{Ca} disappears comparatively rapidly with pedogenesis (Walker and Syers, 1976). *C. macra* is associated with older soils and its P yield is correlated best with surface bound aluminum P (P_{Al}). *C. rigida* is not confined to older soils but its P yield per shoot is correlated with P_{Al} and P_{Fe} rather than with P_{Ca}. O'Conner *et al.* (1972) point out the parallel that exists in adaptation of exotic grasses and its implications for pasture development.

TABLE 1. Partial correlation coefficients between weight of phosphorus in shoots of three Chionochloa species from South Island and soil inorganic phosphorus fractions

Species	Altitude	Ca-P	Al-P + Fe-P	Al-P	Fe-P
C. flavescens	0.554	0.953**	−0.295	0.319	0.385
C. rigida	0.202	−0.170	0.548*	0.606*	0.508*
C. macra	−0.247	0.247	0.460	0.808**	0.602*

Adapted from Williams *et al.*, 1955

Other soil adaptations may have greatly influenced the fate which tussocks have suffered in the course of pastoral use. It has been widely observed (Connor *et al.*, 1970) that tall tussocks, although generally not highly palatable to livestock and of poor nutritive value (MacRae and O'Connor, 1970), vary between species and between sites in their acceptability to stock. In recent years topdressing with superphosphate or with gypsum or elemental sulphur has been observed to increase the acceptability to sheep and cattle of *Chionochloa rigida* and *Festuca novae zelandiae* tussocks as well as adventive grasses and other herbs. *C. rigida* has been found to have the lowest S concentrations in both green blades and sheaths of the tall tussock species in South Island pastoral country. For both this species and *C. macra*, green blade S concentration is correlated with sulphate S extracted from topsoil on a volume basis (Williams *et al.*, 1977b). Sulphur is an endemic deficiency in South Island pastoral country because of low atmospheric returns. The possibility remains that tall tussocks, especially *C. macra* and possibly *C. rubra*, have been preferentially grazed where they were better supplied with soil S.

There can be little question that the tall tussock grasslands have been greatly reduced in area as a consequence of fire and grazing, especially on sunny slopes which are preferred by sheep. Ironically, cattle, which have been promoted by soil conservation interests in recent years to obviate the need for burning, are now on some sites accomplishing the elimination of tall tussocks which a century of fire and sheep grazing failed to do. The tall tussocks are adversely affected by defoliation, especially severe and repeated defoliation (O'Connor, 1963; O'Connor and Powell, 1963; Mark, 1965b, 1969). On an alluvial soil at 700 m in Canterbury, annual leaf production of *C. rigida* exceeds 50m^{-2} dry matter with a total standing crop of 38 MT/ha (Williams, 1977). *C. macra* at 1 000 m in Canterbury has annual leaf production of 33 gm^{-2} and a total standing crop of 16 MT/ha (Williams, 1977). For many decades such tall tussock grasslands were burnt as frequently as every three years in an effort to transform them to short tussock or sward grasslands. As Connor (1964) showed for the Mackenzie country, short grasslands were induced often to altitudes of more than 1 000 m. In Central Otago the relict *C. macra* stands at altitudes often in excess of 1 500 m betray the origins of the now depleted *Poa colensoi* grasslands or cushion and herbfield communities such as were calculated by Bliss and Mark (1974) to produce 126 to 255 g/m^{-2} annually net above ground. The pastoral utility of such cushion communities is extremely low, perhaps lower than that of *C. macra* community from which they were derived, probably within the first few decades of pastoral occupation.

Reductions in primary productivity of hill lands in the drier zones of Otago that have apparently occurred as a consequence of depletion are represented graphically in Figure 1(a) and (b). It is to be noted that higher altitude and lowest altitude zones have been most affected, the lower altitudes especially on sunny aspects, the traditional winter range. The low pastoral carrying capacity of the upland summer range would not seem to justify its continued pastoral use in its present condition except perhaps in rare cases of feed emergency. The possibility of improved water relations at the site, or even downstream, as a consequence of greater fog interception by tall grass and greater throughflow (Rowley, 1970) is an added argument for rest from grazing.

Yet the causes of overgrazing and of the continued pastoral use of such upland sites seem to lie not just in an earlier overestimate of their potential sustained yield but in reduction of resources in another lowland or montane ecosystem. Alienation of lowlands from pastoral enterprises or degradation

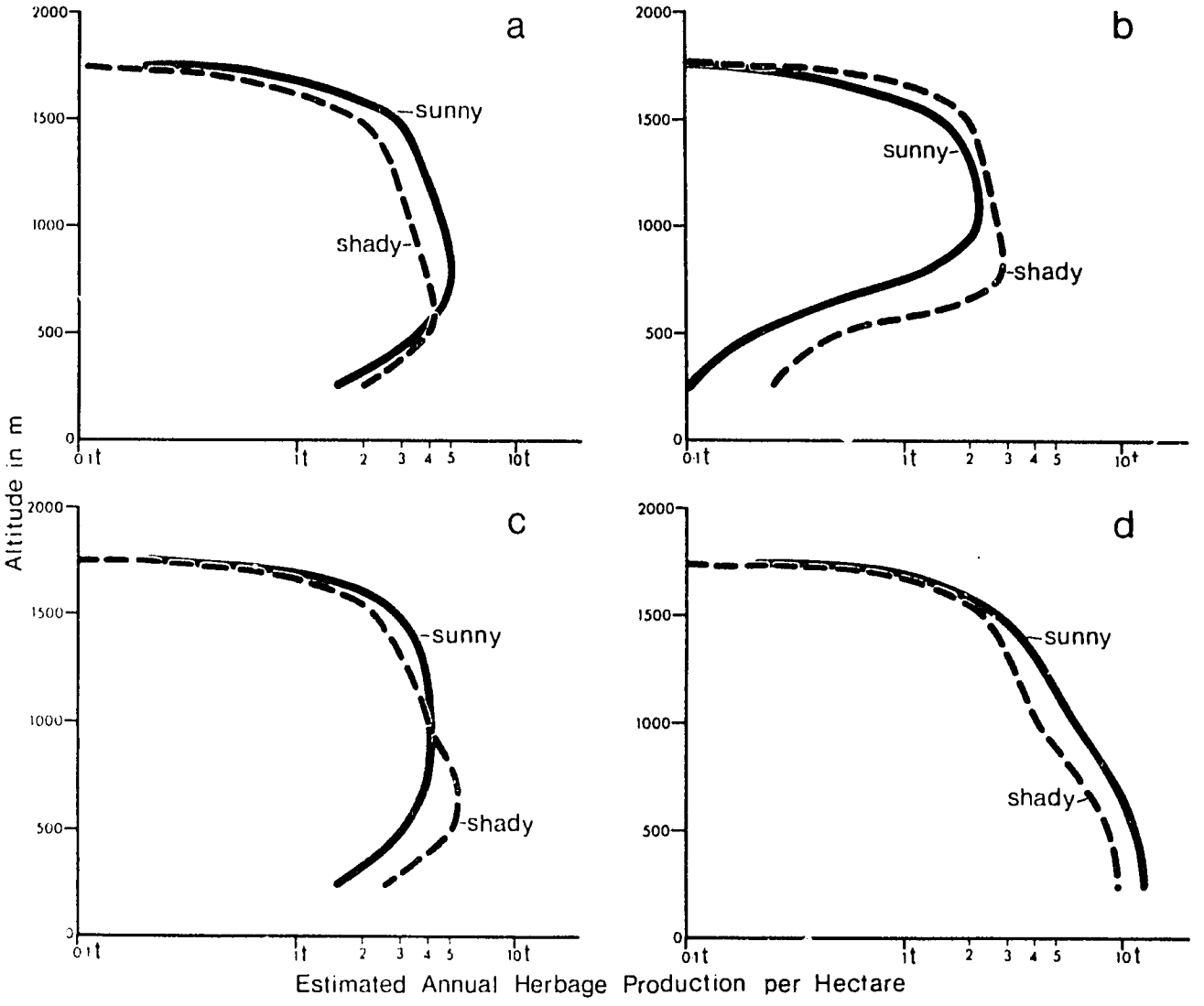

Figure 1. Estimates of total annual herbage production in relation to altitude and aspect in the semi-arid Otago region, New Zealand: (a) pre-European; (b) after pastoral depletion; (c) assuming plant introduction and soil fertility amendment; (d) assuming correction of moisture deficiencies as well as (c) above.

of winter range by drought and rabbits may have forced pastoralists to safeguard their remaining winter feed resources by overexploiting the summer range on the uplands. The remedy for the uplands appears to depend on development of new summer pastures by oversowing and topdressing of mid-altitude slopes and developing often irrigated lowlands for hay meadows and winter feed crops. The potential for this kind of development is illustrated in Figure 1(c) and (d) with progressive removal of soil fertility limitations for legume growth and the correction of water deficits by irrigation wherever feasible. The theoretical marginal returns from legume oversowing and topdressing on the mid-altitude slopes are high (Leamy *et al.*, 1972, 1974) for their deficiency in Central Otago is principally S (Ludecke, 1962). Experience indicates that to achieve the potential indicated there is need for much more intensive livestock management (Hughes, 1974). Furthermore, some development of winter feed resources is essential, even at high cost, if mid-slopes are to be improved and adequately stocked (O'Connor, 1975; Cossens, 1975).

Interaction of Energy, Water, Geochemical, and Grazing Animal Regimes

Somewhat different illustrations of pastoral depletion and of pastoral restoration through the grassland development transition could be drawn for sub-humid and humid zones of the South Island hill lands as for the Central Otago semi-arid zone. In the sub-humid Mackenzie Country in the Waitaki

(O'Connor, 1976a), work is currently being developed as New Zealand's contribution to the UNESCO Man and the Biosphere Program to clarify and quantify these relationships. In that region all four of the regimes I have considered interact to present a major challenge in resource management for the immediate future of hill lands.

First, the region has outstanding radiation regimes, together with high potential evapotranspiration (Coulter, 1975). When moisture is not limiting and gross nutrient deficiencies have been corrected for legumes, yields of herbage well in excess of 13 MT/ha of dry matter have been experimentally measured from better soils (O'Connor, 1966; McLeod, 1974; Scott *et al.*, 1975).

Second, variation is large in annual yields of clover-oversown and topdressed short tussock grasslands in this sub-humid region. At individual sites the range of annual yields of dry matter was from 2 to 15 MT/ha, 2 to 9 MT/ha, 6 to 17 MT/ha in five years (O'Conner *et al.*, 1968) and from 4 to 13 MT/ha in three years, and in the adjacent Rangitata 2.5 to 17 MT/ha in five years (McLeod, 1974). O'Conner *et al.* (1968) demonstrated a highly significant correlation ($r = 0.83^{**}$) between annual herbage yield and rainfall in the spring months, September to November inclusive. Such spring precipitation in inland basins shows high variability (c.v. >40%) (O'Connor, 1976a). Without irrigation, the Mackenzie Basin will be highly erratic in improved pasture production. With irrigation, such pastures on good soils would be highly productive (Scott *et al.*, 1975).

Third, O'Connor and Clifford (1966) demonstrated substantial improvement in fertilizer efficiency from the periodic hard grazing of clover-oversown and topdressed tussock grasslands, in comparison with periodic lax grazing. This improvement was attributed by O'Connor (1966) to acceleration of the mass flow of cyclic nitrogen. As was pointed out by Suckling (1959), herbage production in stock camp areas may be increased at much greater rate than that of hillside grazing areas. The risk of nutrient wastage in such stock-congregating systems is real (Gillingham and During, 1973).

Mob stocking may avert such a costly waste by promoting dispersed "camping" behavior of the animals within the stocked paddock, but it has not yet been proved in large-scale tussock grassland situations. Be that as it may, in no way can pastoralists be expected to increase flocks to provide good grazing management of oversown tussock in both lean and fat years without some reliable alternative feed supply for droughty seasons. Clearly the economics of land retirement for water and soil conservation in high-altitude zones and of irrigation in the intermountain basins must take account of the ecology and economy of mineral cycling through the improved hill pasture and the grazing animal. Sustained research in animal behavior, including diet selection (Hughes, 1975) and in mineral composition of herbage components and blood plasma (Grace and Scott, 1975), is expected to assist such understanding.

ON ADJUSTMENT TO THE IMPERFECT

I have elsewhere (O'Connor, 1973, 1974) attempted an ecologic balance sheet of our New Zealand stewardship. In summary, half the land area of New Zealand is occupied by life systems which are either ecologically or culturally stable and half by systems which remain unstable. So far as cleared hill lands are concerned, geophysics and geochemistry, rather than climate, govern their prospects for the future. If mineral deficiencies are corrected, soils of the lowland hill country can be highly productive in pasture. Adequately topdressed soils of the sub-humid and humid montane zones extending from about 300 to 1000 m can support legume-based pastures of high productivity. In spring, summer, and early autumn, average pasture growth rates are in no way inferior to those achieved in lowland situations in milder parts of New Zealand. The sub-alpine and alpine soils can now be rested and healed where they are in need of such.

The influence of altitude is seen in elongation of winter dormancy. This has little effect on total annual herbage production in the montane zone but may profoundly affect the comparative economy of pastoral use. Ability of livestock to winter outdoors is not gravely affected but the New Zealand farmer's traditional reliance on autumn-saved pasture and on the few kg/ha/day of cool season pasture growth is seriously reduced. Fossil energy subsidies in haymaking and other winter feed provision are at present large and apparently unavoidable. Building animal condition for winter may warrant greater attention in the future than building haystacks or silos.

The world is busy turning over its ecologic conscience and not before time. Guthrie-Smith, New Zealand's doyen of naturalists for many years, and a hill country sheep farmer of very considerable ecologic insight, raised his own doubts in the preface to the third edition of *Tutira* written shortly before his death in 1940. "Have I then for sixty years desecrated God's earth and dubbed it improvement? Such are the melancholy musings that perplex a sheep farmer in concern for his soul."

Mistakes were made in the clearance and settlement of New Zealand hill lands. Many of these mistakes have not yet been corrected. Some may never be. A reader of Samuel Butler's ironical essay on early days in the Canterbury settlement, written more than a century ago, may discern that such

mistakes were made by judging too readily from appearances. As I have suggested in a recent essay on the condition of the mountains (O'Connor, 1976b), we display a similar propensity to judge from appearances. The myths that we continue to tell ourselves are made the substitute for understanding. We may even prefer a precise answer for a part of our problem to a true understanding of what our problems are. Our genius for isolating the problems we intend to study from the complex and varied hill land use systems in which they are, must surely be shadowed by the ghost of the economist who warned that everything was connected to everything else and there is no such thing as a free lunch.

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DISCUSSION

J. Munro (Wales). I think we all must agree that the land Kevin has been talking about is one of the most beautiful hill ecosystems in the world and also one of the most fragile. Obviously, its survival in the future is very critical indeed.

G. C. Anderson (West Virginia, USA). Your illustrations of the degradation of Canterbury high-country grasslands were followed by a slide showing a steady decline in the number of sheep in that country from 1900 to 1950, except for a partial recovery during the Great Depression of the 1930's. You made no mention of cattle in this situation. I understand there has been some increase in cattle as sheep numbers have also increased in recent years. Were cattle involved in the part of the island you described?

O'Connor. Until 1960, the only zones of the tussock grasslands that carried cattle in any numbers were the runs in the glaciated valleys of the humid zone where they were an integral part of management and probably remained fairly static in numbers. We lack detailed per run cattle statistics before 1966. From about 1960, when cattle were promoted to reduce the need for burning and when world beef market prospects were good, cattle numbers increased substantially. For the six-year period from 1966, cattle numbers increased by 102% in the high country as a whole, by 135% in the Canterbury sub-humid zone, and by 71% in the Canterbury humid zone from a larger breeding base. In the same period, sheep numbers increased by 9%, 15%, and zero, respectively. More recently, as cattle market prospects have declined, increases in stock units with continued pasture improvement tend to be as sheep. The overall annual rate of increase 1966-72 in calculated stock units in the South Island high country was 3.5%.

84.
Energetic Efficiency of Animal Production in Hill Environments

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Very little direct data concerned with the energetic efficiency of animals in hill environments exists. Thus, efficiency coefficients must be synthesized indirectly from values determined under appropriate arrays of controlled experimental conditions. Based on the transposition of data obtained under such conditions, it is expected that a wide range of efficiency exists because of the great range of hill conditions to which animals are exposed, e.g., various levels of altitude, temperature, solar radiation, slope, moisture and soil nutrients; various kinds and amounts of vegetation; and various degrees of climatic and physical rigors on animals.

Data, such as those of the Meat and Livestock Commission (1973), provide a starting base for projecting comparative efficiencies under various production situations. For example, in Britain the average number of lambs produced per ha in 1972, under several conditions, were as follows: 10, upland flocks; 11, extensive lowland grazing; 13.6, lowland flocks on arable land; and 17, intensive grassland flocks. These data infer that the efficiency of sheep production on hill land might be increased by improving the sward, increasing the stocking rate and lambing percentage, supplemental feeding, and improving the environment at critical times.

In the context of hill land ecosystems, it will be assumed in this paper that the major alternative use of land includes ruminant and forage or browse production. Although the energetic efficiency of ruminants under a range of conditions will be emphasized here, examples of the efficiency of other animals will be cited to establish the position of ruminants in the energetic-efficiency hierarchy. Also, special attention will be given to the dietary and fossil energy requirements of protein production by ruminants under intensive and extensive conditions.

ENERGETIC EFFICIENCY OF CONFINED, HAND-FED ANIMALS

Inter-specific Peculiarities of Animals

An examination of the comparative efficiency of animals is complicated by differences between kinds of animals in their: (a) gastrointestinal architecture, (b) nature of the predominant digestive agents, (c) location of the digestive agents, and (d) major sites of digestion and absorption. These characteristics correspondingly determine: (a) the chemical and physical nature of an animal's normal or usual diet, (b) the rate of digestion and of ingestal passage, and (c) the chemical nature of the absorbed products of digestion. Other distinguishing features of the physiological machinery are correlated with a specific combination of these characteristics, and they are peculiar to a given kind of animal. On the basis of their differentiating characteristics, animals may be classified in one of the following groups: (a) simple-gutted animals (SGA), including man, rat, pig, dog, and chicken; (b) non-ruminant herbivores (NRH) including the rabbit, guinea pig, and horse; and (c) ruminants, including sheep, goat, cow, water buffalo, deer, alpaca, wildebeest, and many others (Reid, 1974). Many of the digestive and metabolic characteristics and the efficiency of energy utilization are similar for the animals in a given classification group.

In this section, the efficiency with which dietary energy is utilized to support individual body functions concerned with food production during the production period will be considered briefly. This will be accomplished by examining: (a) the partition of digestive and urinary losses of dietary energy, the residue of which yields metabolizable energy (ME), and (b) the utilization of ME by various kinds of animals to yield food products. The nature of this kind of treatment reflects the energy cost of food production during only the immediate production period and does not include the overhead energy costs such as those of rearing and maintaining the breeding stock or of reproductive and mortality losses incurred in the production process.

Partition of Energy Losses in Feces, Digestive Gases, and Urine

A spectrum of the partition of dietary gross energy (i.e., heat of combustion of the diet) by the animals of the three gastrointestinal groups is shown in Table 1. Within groups, the magnitude of the energy losses as digestive gases (chiefly CH_4), feces, and urine depends greatly on the nutritional quality of the diet. The values shown in Table 1 reflect the range in the quality of diets and in the environmental conditions to which animals sometimes are exposed.

TABLE 1. Partition of dietary energy by various kinds of animals

Energy in:	Simple-gutted Animals (SGA)[a]	Non-ruminant Herbivores (NRH)[b]	Ruminants[c]
Gases	0-0.5	2-7	5-12
Feces	2-40	10-70	10-60
Urine	1-3	3-5	3-5
Metabolizable Energy	56-97 (80)[d]	18-85 (70)[d]	23-82 (60)[d]

[a]SGA = man, rat, pig, chicken.
[b]NRH = rabbit, guinea pig, horse.
[c]Ruminant = sheep, cattle.
[d]Values under good commercial practice.

However, the higher rates of energy wastage are either rare, periodic, representative of one poor-quality feedstuff, or uneconomical in practice. Conversely, the lower rates of loss are representative of those associated with the most effective diets. The dietary gross energy, minus the sum of the energy losses as digestive gases, feces, and urine, is the ME.

In Table 1, the ME values in parentheses represent those of productive diets such as are provided in commercial practice in the USA. These values reflect the decided difference in the metabolizability of energy among the animals of the SGA, NRH, and ruminant groups. Also, differences exist between some of the animals within a given group. For example, when the same diets were ingested, the dietary energy lost in the feces was greater: by *Bos taurus* than by *Bos bubalis* (Johnson, 1966); by sheep than by hartebeest and duiker (Arman and Hopcraft, 1975); by Thomson's gazelle and eland than by sheep (Arman and Hopcraft, 1975); by sheep than by llama and guanaco (Hintz *et al.*, 1973); by sheep than by alpaca (Fernandez Baca, 1966); and by red deer than by sheep (Maloiy and Kay, 1971). In most of these comparisons, the differences in digestibility were small; however, those between water buffalo and cattle and between the camelidae and sheep were quite marked.

The magnitude of the fecal energy loss by ruminants as shown in Table 1 does not reflect that which occurs under some hill conditions. For example, Munro *et al.* (1973) observed that the digestible organic matter of *Nardus* and *Molinia* declines from 55 to 35% and from 50 to 15%, respectively, from July to the end of November. Thus, the fecal energy loss in November would be approximately 65 and 85% of the energy ingested by animals grazing *Nardus* and *Molinia*, respectively. It is apparent, therefore, that the ME value of some diets ingested by ruminants might be as low as 7 to 10%.

Utilization of ME

The model by which certain kinds of influences on the utilization of ME and the peculiarities of various kinds of animals will be examined here is represented by Fig. 1. This examination of animal energetics employs the relationship between the ME intake (X) above maintenance and the resulting energy balance (Y), i.e., energy gained by the body or put into other food products. Both of these variables will be expressed per kilogram of body weight raised to the power, 0.73; this parameter will be employed as the index of metabolic body size (MBS). Since it is now well established, in all animals which have been studied, that the energy balance is a linear function of the ME intake above the maintenance level, the relationship can be derived with a minimum of two values. Thus, requisites of this method are the corresponding positive energy balances of two or more ME inputs within treatment. The relationship between the two variables provides: (a) the slope, which is the index of efficiency with which ME supports a given body function, sometimes called the rate of net utilization of ME for a specific body function; and (b) the ME-intake intercept at zero energy balance, i.e., the amount of ME that just prevents a gain or loss of body energy; this value represents the ME requirement of maintenance.

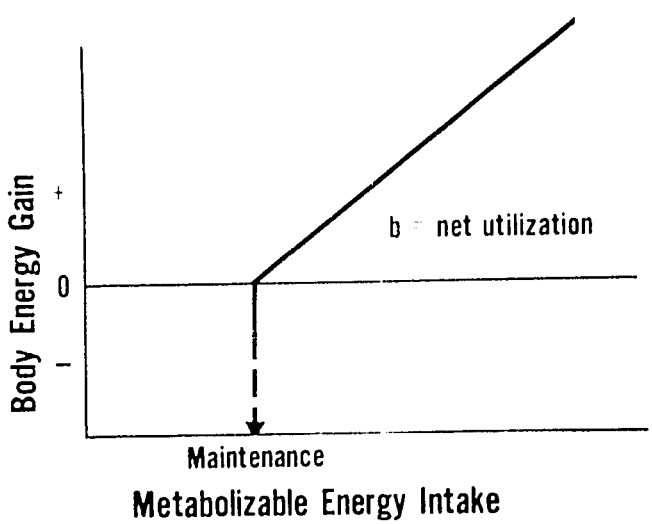

Figure 1. Relationship between the metabolizable energy intake and body energy gain.

Metabolizable energy is represented by the organic matter that reaches the body tissues and is the fraction of dietary energy capable of being transformed to support body functions and to yield food products. The efficiency with which ME is utilized is influenced by, or associated with, certain environmental conditions, physical activity, the sex and

TABLE 2. Energy requirement of maintenance and the net utilization of metabolizable energy for body gain associated with kind of animal, dietary characteristics, and the animal's activity, sex, and ambiency

Expt. No.	Animal	Main Treatment(s)	Other Distinguishing Conditions	Net Utilization[a]	Maintenance Requirement[b]	Source
				(% of ME)	(Kcal/MBS/day)	
1	Woman (21 yr., 129 kg)	No exercise	Obese subject; each of 3 levels of energy input imposed during 4- to 8-week period	89.2	73.9	Buskirk *et al.* (1963)
		Exercise		84.8	92.0	
	Man (19 yr., 145 kg)	No exercise		78.7	72.8	
		Exercise		76.1	99.2	
2	Pig (initial body wt. *ca.* 100 to 180 kg)	Corn and barley	Three expts.; two basal diets of usual ingredients provided at 4 to 6 levels of energy input	73.6	88.6	Nehring *et al.* (1960)
		Barley and oats		81.1	116.1	
		Barley and oats		76.4	101.9	
3	Chicken (mature, 3.5 to 4.8 kg)	4% fat & 28° C	4% fat diet contained 80% corn meal;	73.0	84.6	Shannon and Brown (1969)
		4% fat & 22° C	32% fat diet contained 29% corn oil	69.2	99.8	
		32% fat & 22° C		84.3	95.2	
4	Rabbit (9–12 mos. old)	2 levels of input above maintenance	Diet of 60% wheat + 40% hay; temperature, 17.8 to 22.8° C	70.5	106.5	Hellberg (1949)
5	Guinea pig	3 rates of growth	Three levels of energy input; 28–30° C.	69.6	86.8	Knudsen (1968)
6	Sheep (15 mos. old)	Long hay	Six levels of input	41.9	95.8	Blaxter and Graham (1955)
		Pell. gr. hay	Eight levels of input	51.7	88.9	
7	Sheep (8 and 20 mos. old at beginning)	Chopped hay	Each diet fed at 3 levels same hay in all diets; slaughter-analysis experiment	30.8	91.5	Paladines *et al.* (1964)
		Pell., gr. hay		43.4	86.7	
		Pell., 50% hay + 50% corn		56.9	84.2	
8	Sheep (3½-yr.-old ewes)	40% hay + 60% concentrates	Each of 5 levels of input imposed during 10-week period	62.5	87.9	Marston (1948)
9	Sheep (6–7 mos. at beginning)	Alf. hay alone or with maize; 2 levels of each	Rams	57.6	88.0	Bull *et al.* (1970)
			Ewes	65.5	87.0	
10	Cattle (steer, 2 yr., 614 kg)	24% hay + 76% concentrates	Diet fed at 5 levels of input	21.3	107.0	Mitchell *et al.* (1932)
11	Steers, mature	66% hay + 34% oats	Each steer fed each of 5 levels; each wether fed at each of 6 levels	54.6[c]	106.4[c]	Blaxter and Wainman (1961)
	wethers, mature			53.6[c]	74.4[c]	

[a]Net utilization for body gain of ME ingested above maintenance level.
[b]Maintenance requirement expressed as kilocalories of metabolizable energy (ME)/MBS/day.
[c]These data were derived from the authors' data for positive balances; the MBS values were computed from the fasting body weight.

gastrointestinal architecture of animals, and a number of dietary characteristics. For example, deficient amounts of protein and of certain vitamins and mineral elements in the diet, and imbalanced assortments of absorbed amino acids reduce the efficiency with which ME is utilized for maintenance or production by animals. Since a detailed account of various influences and associations is given elsewhere (Reid, 1974), only a few samples will be provided here.

In Table 2 are examples of the relationships of a few dietary characteristics, physical activity, sex, and ambient environment on the ME requirement of maintenance and the net utilization of ME for body gain in man and certain meat-producing animals. The examples are designated by experiment numbers as follows for animals of the three gastrointestinal groups: SGA, 1–3; NRH, 4 and 5; and ruminants, 6–11.

The data designated as Experiment 1 were derived

from the extensive studies made by Buskirk *et al.* (1963) of obese human human subjects. During periods of 4 to 8 weeks, each of three levels of energy intake was provided with and without exercise on a treadmill (12 km per day at the rate of 5 km per hour on a 5% grade). However, because of chafing of the contacting body surfaces, the subjects were allowed to rest on an upright bar and did not perform the full amount of work planned. Some of the diets were constituted from a "Metrecal" base and others were formulated from milk solids, dextrimaltose, and corn oil ingested as liquids. The net utilization of ME within subject was not influenced by exercise; however, the ME requirement of maintenance was decidedly increased by exercise.

Experiment 2 represents an extensive series of energy-balance experiments with pigs involving two basal diets characterized by corn or oats. Each basal diet with or without increments of barley meal was provided at four to six levels of input to 4, 6, or 8 pigs as they grew from a body weight of about 100 to 180 kg (Nehring *et al.*, 1960). The net efficiency of body gain observed in these studies is of the same order of magnitude as that reported for other SGA. The ME requirement of maintenance was considerably higher for the pigs ingesting the diets high in barley and oat meal than for those whose diet contained 42% of corn meal with 42% of barley meal, plus the same protein supplements. Diets high in barley and oats are relatively high in fiber and, accordingly, might require a greater energy expense in the muscular work of digestion.

In Experiment 3, Shannon and Brown (1969) examined the influence of dietary fat level (approximately 4 and 32% of dry matter) at an ambient temperature of 22° C, and that of ambient temperature (22 and 28° C) when the 4% fat diet was fed to mature Light Sussex cockerels weighing 3.5 to 4.8 kg. Energy exchange was derived from the continuous measurement of oxygen consumption and carbon dioxide production during 22 hours of each 24-hour metabolism period. The remaining 2 hours were employed for excreta collection and giving the next meal. Each bird was maintained on a given intake level for seven days, the last three of which were spent in the respiration calorimeter. At least four weeks were allowed for acclimatization at either temperature.

At 22° C, the maintenance requirement was about the same for the birds fed the two diets, but the net utilization of ME for body gain was about 22% greater for the birds ingesting the 32% fat diet than for those receiving the 4% fat diet. This result is similar to that observed in rats (Forbes *et al.*, 1946; Chudy and Schiemann, 1967). Increasing proportions of fat in the diet increased the rate of energy storage also in sheep (Swift *et al.*, 1948). It appears that dietary fatty acids are used preferentially to other nutrients to form body fat. The higher energetic efficiency of high-fat diets undoubtedly results from the direct incorporation of dietary fatty acids into triglycerides. This direct incorporation circumvents the energy cost of *de novo* synthesis of fatty acids from other dietary sources, a process requiring reduced nicotinamide adenine dinucleotide phosphate.

The chickens employed in Experiment 3 (Table 2) that were fed the 4% fat diet required more ME for maintenance at the ambient temperature of 22° C than at 28° C. This indicates that 22° C is below the range of thermal comfort of chickens so feathered. However, the net efficiency of body-energy gain was not different for the two temperatures.

The data for Experiment 4 (rabbits) and Experiment 5 (guinea pigs) indicate that the net utilization of ME by NRH is somewhat lower than that by SGA but higher than that by ruminants. Experiment 4 was conducted with mature rabbits weighing approximately 3 kg (Hellberg, 1949). A diet consisting of 60% of coarsely ground wheat and 40% of ground hay was fed at six levels above that of maintenance. Energy storage was determined at ambient temperatures ranging from 17.8 to 22.8° C, with most balances being determined at a temperature below 20° C. Whether the maintenance requirement would have been lower at a higher ambient temperature than that determined (i.e., than 106.5 Kcal of ME/MBS/day) is not known. However, some investigations have revealed that the lower critical temperature of the rabbit might be as high as 28° C.

The data obtained in Experiments 6–11 (Table 2) were selected to demonstrate the usual range of nutritional influence on the energetic efficiency of sheep and cattle, and the relationship of sex to the net utilization of ME by sheep.

The data for Experiments 6 and 7 (Table 2) show that when pelleted, ground hay is ingested by sheep, the net utilization of ME for body gain is greater and the ME requirement of maintenance is somewhat less than when hay from the same source is fed in chopped form. The fundamental reasons for these differences are not precisely known. However, a larger proportion of the carbohydrates of finely ground forage escapes fermentation in the rumen and is digested in the small intestine (Thomson *et al.*, 1972; Beever *et al.*, 1972); and, therefore, more carbohydrates might be absorbed as simple sugars rather than as volatile fatty acids from ground forage than from chopped or long forage. Also, the muscular work of digestion of ground forage might be less than that for chopped or long forage.

The studies of Osuji *et al.* (1975) demonstrate that the energy cost of eating is influenced by the physical form of grass. The costs (kcal/kg of dry matter ingested) were as follows for various forms: chopped, fresh grass, 93; chopped, dried grass, 57; and pellet-

ed, dried grass, 5.7. The energy costs of rumination ranged from 4 to 11% of that of eating. Some of the same workers (Webster *et al.*, 1976) showed that the combined energy costs of eating, ruminating, fermentation, and work of gut tissues are 30.0, 27.9 and 24.5%, respectively, of the total heat increment of sheep ingesting grass of the three physical forms. The estimates of Webster *et al.* (1976) indicated the energy cost of work by the gut tissues was the same (21% of the total heat increment) irrespective of the physical form.

The addition of corn meal to the hay employed in Experiment 7 resulted in a further improvement in efficiency and some reduction in the maintenance cost. In his classical experiment (Experiment 8, Table 2) carried out with 3.5-year-old Merino ewes fed a diet consisting of 50% crushed wheat, 10% cane molasses, and 40% ground alfalfa hay, Marston (1948) observed a net efficiency of 62.5% and a maintenance requirement of 87.9 Kcal of ME/MBS/day. Bull *et al.* (1970) obtained similar values (Experiment 9, Table 2) for female Southdown sheep fed a diet of very high-quality ground alfalfa hay and corn meal. However, male Southdowns with intact gonads and receiving the same diets had a decidedly lower net utilization for body gain, but their maintenance requirements were the same as those of the females.

The most conspicuous characteristic of the data for cattle fed mixed concentrate-hay diets (Experiment 10), as compared with those for sheep (Experiments 7, 8, and 9), is the higher ME requirement of maintenance. In Experiment 11, Blaxter and Wainman (1961) compared adult wethers and steers directly. They fed a diet of two parts poor-quality hay and one part oats at each of five levels of energy input to each of three steers weighing 380, 460, or 490 kg during fasting, and at each of six levels to each of three wethers weighing 39, 55, or 63 kg during fasting. As shown in Table 2, the net utilization of the ME ingested above the maintenance level was not different for the two kinds of animals, but the ME requirement of maintenance was 74.4 and 106.4 Kcal/MBS/day for the wethers and steers, respectively. The latter values were computed for the present study by using the fasted body weights to determine the MBS.

The indigenous plants of some hill lands, at least during certain seasons, are highly lignified and poorly utilized by animals. Since cereal straws are among the lowest quality forages examined calorimetrically, the efficiency with which they are utilized by ruminants may represent the low end of the utilization spectrum of hill land plants. A summary of certain compositional and nutritional data for oat and wheat straws, alkali- and sulfite-treated rye straw, meadow hay, and a high-quality, immature alfalfa hay is recorded in Table 3. These data show a high degree of correlation between the proportion of the ME (and of the gross energy, GE) put into body gain and either the percentages of ME, digestible energy (DE), or the cell-wall components. The net utilization of ME provided by wheat straw for body gain has been as low as 8% in other German studies. Although the concentrations of ME are not recorded in Table 2, the net utilization of ME for body gain by the ruminants increased with increasing concentrations of ME in those experiments, too. Also, there is evidence of a decreasing requirement of ME for maintenance as the ME concentration of the diet increases.

The energy of alkali- and sulfite-treated rye straw (Table 3) was found by Kellner (1900) to be utilized by cattle for body gain as efficiently as that of high-concentrate diets (Mitchell *et al.*, 1932) (Table 2). Although it is expensive in terms of fossil energy,

TABLE 3. Comparison of composition and nutritive value of forages of various quality

Forage	Proportion of GE		Net utilization of composition[a]			
	DE	ME	ME	GE	ADF[b]	Cell Wall[c]
			Percent			
Oat straw[d]	43.2	35.8	36	13	47	70
Wheat straw[d]	41.8	31.6	17	5	54	85
Alk.- and Sulf.-tr. straw[d]	87.2	75.5	63	48		
Meadow hay[d]	58.7	47.9	41	20	35–40	55–65
Alf. hay[e]	73.1	54.4	60	32	25	35

[a]Estimated from data of Van Soest (1973).
[b]ADF = acid detergent fiber = lignocellulose + SiO_2.
[c]Cell wall content = lignin + cellulose + hemicellulose + cutin + silica + tannins.
[d]Kellner (1900).
[e]Bull *et al.* (1970).

chemical treatment represents an alternative method of utilizing the floral mass of hill lands.

The salient points demonstrated in Tables 2 and 3 are: (a) the net utilization of ME for body gain is greatest in SGA, least in ruminants, and intermediate in NRH; (b) in ruminants, the net utilization may range from about 10% for highly lignified forage to about 65% for the highest quality diets; (c) the energy of forages reduced to small particle size is more efficiently utilized by ruminants than is that of long or chopped forages; (d) ME is utilized for body gain more efficiently by female ruminants than by male ruminants; however, the ME requirement of maintenance is the same for both sexes; (e) the maintenance requirement increases with increasing physical activity; is greater at ambient temperatures both above and below the range of thermal comfort than within; is higher in cattle than in sheep; and is inverse to the concentration of ME in the diet of ruminants; and (f) alkali and sulfite treatment of highly lignified cellulose materials such as cereal straws greatly improves the nutritive value.

SOME CONDITIONS PECULIAR TO HILL LAND THAT MIGHT INFLUENCE FORAGE QUALITY AND ANIMAL EFFICIENCY

Climate

In the context of pasture production, climate generally deteriorates with increasing altitude (Alcock, 1969; 1975), and the predicted climatic changes indicate that the deterioration might be accentuated in the future (Bryson, 1974). There are four fundamental components of climate that affect plant growth: (a) solar radiation (affecting photosynthesis), (b) ambient temperature (affecting especially leaf growth and respiration), (c) water (affecting leaf growth and photosynthesis), and (d) carbon dioxide concentration (affecting photosynthesis). Assuming that water, soil nutrients, and carbon dioxide are adequate, the major climatic factors affecting plant growth and composition are light intensity and temperature (Alcock, 1975; Deinum, 1966). These are influenced by altitude, direction of exposure, slope of hill, and the extent of cloud cover.

Light Intensity and Soil Temperature

Solar radiation on hills is as much as 20–25% less than that on lowlands in Wales at the beginning of summer and during the early- and late-spring months (Alcock, 1975). By mid-June, the solar radiation is 8–10 times that during the period of November to February. Corresponding temperatures were 2–3° C lower on hills than on lowlands during the summer and about 5° C lower during the period of December to April. Accordingly, the production of forage dry matter was greater on the lowlands (Alcock, 1975).

An attempt has been made in Table 4 to generalize qualitatively some of the effects of increasing degrees of light intensity and temperature on the yield, chemical composition, and digestibility of forage (Alberda, 1957, 1965; Beevers and Cooper, 1964; Burton *et al.*, 1959; Deinum, 1966). Interactions of light intensity or temperature with fertilization rate, water status, species of plant, and growth stage are known to occur. As a consequence, deviations from the generalizations cited in Table 4 have been observed, and the extent of the trends recorded varies with the interacting conditions. Accordingly, the quality and quantity of forage and the resulting responses of animals are expected to vary from hill to hill.

TABLE 4. Some effects of light intensity and temperature on the production and nutritive qualities of forage

Component or Characteristic	With Increasing: Light intensity[a]	Temperature[a]
D. M. output	Increases	Species optimum; above and below optimum, it decreases
Protein conc.	Decr. (usually)	Usually higher above and below optimum
Soluble CHO	Increases	Decreases (usually)
Fiber conc.	Decreases	Increases
Ash. conc.	Decr. (usually)	Increases (usually)
Digestibility	Increases	Decreases

[a]Interactions with fertilization rates, moisture, species, and season occur; deviations from these generalizations have been reported; effects of a long day length may be the same as high light intensity.

Plant growth occurs within a wide temperature range; however, each plant has an optimum temperature above and below which the growth rate is less. The temperature at which growth is optimal is not necessarily the temperature at which nutritive qualities, e.g., protein content, are enhanced (Alberda, 1965). For example, the protein content is higher in plants grown above or below the optimum temperature for dry-matter growth than in those grown at the optimum growth temperature (Alberda, 1965; Beevers and Cooper, 1964). Because of the influence of temperature on lignification, the digestibility of tropical forages is characteristically low.

Effects of Ambient Conditions on Animal Efficiency

Any condition that results in an ambient temperature below or above the zone of thermal comfort results in an increase in heat production by animals.

Accordingly, the dietary energy requirement is increased and the efficiency is reduced. In the context of the hill environment, the rate of cooling and the zone of thermal comfort depend upon the ambient temperature; the infrared radiation intensity; wind velocity; rain; tissue and fleece or hair insulation; and level of feed intake (Joyce and Blaxter, 1964).

At maintenance levels of feeding under chamber conditions (e.g., air velocity of 0.6 to 1 km/hr) the critical temperature (viz., the air temperature below which heat production increases) of sheep is: 30° C when the fleece length is 2 mm; 20° C when the fleece length is 18 mm; 10° C when the fleece length is 35 mm; and −3° C when the fleece length is 100 mm. Based on a study of some typical Scottish hill land conditions, Joyce and Blaxter (1964) estimated minimal heat production figures. Those data indicated that the energy requirement for maintenance of sheep at −10° C and an air velocity of 0.8 km/hr was 15% greater with a 50 mm fleece and 126% greater with a 10 mm fleece than it was within the range of thermal comfort. At an air temperature of 5° C and an air velocity of 12.5 km/hr, the maintenance requirement was 8% greater with a 50 mm fleece and 103% greater with a 10 mm fleece than it was within the zone of thermal comfort.

Joyce and Blaxter (1964) noted that the resistance to cooling resulting from tissue insulation is greater in Scottish Black-face sheep than in Cheviots or a Down-cross sheep. Lucas (1975) suggested that this could account for an increase of 4° C in the critical temperature or a 10% reduction in the energy requirement of maintenance at low ambient temperatures in Scottish Blackface sheep as compared with Down-cross sheep.

Sheep Adapt to Prolonged Exposure to Cold

Exposure to wind results in a gradual decrease in the degree of vasodilation of fleece-covered areas. As acclimatization occurs, the rate of body cooling gradually declines. Acclimatization is associated with a temporary increase in metabolic rate, a postponement of vasoconstriction of the extremities and increases in non-shivering heat production, skin temperature of extremities and cold-induced vasodilation. Some breeds of sheep are quite different from others with respect to the acclimatization characteristics (Slee, 1968, 1972; Sykes and Slee, 1968, 1969a, b; Lucas, 1975). For example, Scottish Blackface exhibit a greater degree of acclimatization than do Welsh Mountain or Down breeds; on a low plane of nutrition, the Welsh Mountain sheep acclimatize to a greater degree than do the Southdowns. Thus, it is expected that the energy cost of maintenance and the efficiency of production varies among breeds under hill environments.

Energy Cost of Grazing

As compared with that determined under housed, hand-feeding conditions, the maintenance requirement of freely grazing sheep (Graham 1964; Whitelaw, 1974; Corbett *et al.*, 1971; Young and Corbett 1972a,b) and cattle (Reid *et al.*, 1958) ranges from 10 to 90% more. Grazing sheep with a full fleece required 43 to 64% more energy and similar sheep after shearing required 56 to 91% more energy for maintenance than did housed sheep (Young and Corbett 1972a, b). On the other hand, when forage is abundant, freely grazing animals graze selectively and thereby upgrade their diet considerably (Hardison *et al.*, 1954). This effect tends to diminish the energy cost of maintenance in grazing.

The energy cost of grazing depends upon the extent of abundance of forage, the distance walked, the slope of land, the work of prehension, fleece or hair length, and other determinants. The significance to the energy economy of animals of the slope of land and the insulating characteristics of the body is greater in the hill-land environment than it is under lowland conditions. In his study of the energy cost of locomotion, Clapperton (1964) calculated the decrease in energy retention by sheep between resting and walking on a level treadmill and between horizontal walking and walking on an inclined treadmill. The apparent cost of horizontal work was 0.59 ± 0.03 cal/kg-m. The decrease in energy retention resulting from walking on an inclined treadmill as compared with that retained in horizontal walking was expressed as the energy expended in raising vertically 1 kg of body weight by 1 m. The mean cost of vertical work was 6.36 ± 0.32 cal/kg-m. However, the cost of vertical work was greater at a low speed than at a high speed, and it was greater at a high level of feeding than at a low level of feeding. Thus, depending on the degree of slope, grazing on hill land demands an energy cost greater than that on flat land, reaching a cost for the impractical vertical slope which is 10.8 times greater than it is on the horizontal plane.

Relationship of Energy Intake and Efficiency of Animal Production

Energy intake is the major force driving animal production. As shown in Fig. 2, the energy cost of maintenance as a proportion of the total energy intake declines as the intake level increases. Thus, the gross efficiency (i.e., the animal output per unit of energy input) increases with increasing intake. This reflects the dilution of the maintenance cost with increasing levels of intake. A comparison of situations B and C (Fig. 2) reveals that an intake equivalent to three times that of maintenance represents two times as much energy for production as does an intake equivalent to two times that of maintenance.

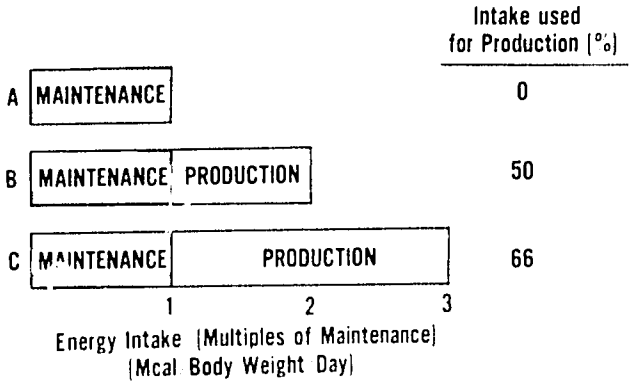

Figure 2. Partition of the dietary energy intake between maintenance and production.

Various strategies are known to intensify the energy intake by ruminants: (a) Harvesting or grazing of immature forage, (b) encouragement of selective grazing or feeding, (c) the breeding of late-maturing cultivars, (d) the chemical treatment (e.g., alkali or sulfite) of lignified forage, (e) the pelleting of finely ground forage, and (f) the feeding of increasing proportions of concentrates. The same strategies increase the DE and ME concentrations of the diets ingested by ruminants.

Although dairy cows can produce as much as 5 000 kg of milk per year and beef cattle can gain as much as 1.25 kg per day on an all-forage diet, the forage must be of unusually high quality for such levels of output to be attained. Such levels of production can be reached or exceeded by some of the strategies cited above. However, the fossil energy costs of certain strategies, viz., chemical treatment or artificial dehydration and pelleting of forage and the feeding of concentrates, are high. Because of the need for N fertilizer to obtain high yields of non-legumes, legume forages yield more DE per unit of fossil energy put into the production system than do non-legumes.

In an experiment in which Oltjen *et al* (1971) fattened steers to the same final body weight on either an all-concentrate or a pelleted, ground hay diet, the rates of gain were 1.05 kg/day by those on the all-forage diet and 1.27 kg/day by those fed the all-concentrate diet. However, 35 more days were required by the all-forage fed animals to reach the same weight as the steers fed the all-concentrate diet. Thus, the energy cost of maintenance was greater for the animals fed the all-forage diet. Accordingly, the higher energy cost of the slower turnover rate of animals receiving all-forage diets must be weighed against the higher fossil energy requirement of producing concentrates as an energy source for animal production. In critical energy-demand situations, it may be economically and energetically more strategic to provide animals some concentrates despite the lower fossil-energy cost of producing forages.

Under hill-land conditions, it is expected that the energy concentrations of forage vary to the same degree as that of the forages for which data are summarized in Table 3. Also, a wide range in voluntary intake is expected. Sheep fed oat straw voluntarily ingested only 22% (Greenhalgh and Reid, 1971) and 50% (Blaxter *et al.*, 1966) as much dry matter as they did when they were fed only dried grass which was about 70% digestible. The intake of energy by ruminants grazing shrubs may be even less than that of the same animals fed cereal straws. Thus, the energy intake of ruminants grazing hill lands may range from that which is inadequate to support maintenance to that which is equivalent to the intake under lowland grazing conditions (Russel *et al.*, 1976). Depending on the nature of the flora, animal productivity may be benefited by mixed grazing involving two or more ruminant species (Connolly and Nolan, 1976).

SOME ALTERNATIVE USES OF HILL-LAND FLORA

Use of Flora as Substrate to Produce "Single-cell" Protein or Soluble Sugars

The utilization of photosynthetically produced organic matter as substrate for the growth of microorganisms represents an alternative use of hill-land flora to produce protein for man and animals (Bellamy, 1976). The state of technology for the production of "single-cell" protein from the soluble carbohydrates is distinctly more advanced than that of the production of microorganismal protein from the lignocellulose fraction. A number of pr cesses for the utilization of soluble carbohydrates have been developed. In some methods of "single-cell" protein production, e.g., by yeast, rates of soluble sugar utilization of 10 to 30 gm/liter/hr have been reported. Unfortunately, at the present time, no microorganisms are known to utilize lignocellulose at rates approaching commercial significance (1 to 5 gm of cellulose/liter/hr) (Bellamy, 1976). Thus, in order to utilize cellulose, the lignin must be removed or modified. Although this may be accomplished by the use of a variety of chemical agents, it is expensive in money and fossil energy. Also, methods involving alkali treatment and depolymerization of cellulose by the enzymes of the mold, *Trichoderma viride*, have resulted in the production of soluble sugars (Mandels *et al.*, 1974). Such sugars may be used as energy sources either directly by animals or through fermentation by yeasts or bacteria to produce "single-cell" protein.

At the present time, technical problems and the monetary and energy expense of utilizing lignocellulose as soluble carbohydrates or with which

to produce protein are too great to make these viable alternatives of hill land floral utilization. Future research may result in more economic ways to utilize lignocellulose which comprises 25 to 70% of the hill land floral dry matter.

Liberating Cellulose from Lignin

The major deterrent to the utilization of lignocellulose by ruminants is lignin. The amount of lignin is as high as 15 to 20% in mature forages and 30 to 40% in wood products. Breaking the ligno-cellulose bonds or the removal of the lignin greatly improves the utilization of cellulose by ruminants. Nehring *et al.* (1965) observed that purified cellulose was at least as good as sucrose as an energy source for sheep and cattle. The net utilization by cattle of the ME provided by cellulose purified by alkali and sulfite treatment of rye straw was 63% in studies reported by Kellner (1900). That level of utilization is as great as that obtained with high-concentrate diets. In experiments in which sheep fed standard fattening rations were compared with those fed rations containing 66 or 70% of sulfite-degraded wood cellulose, the rates of body weight gain were 72 to 83% as great by those fed the wood cellulose diets as by those which received standard diets (Dyer *et al.*, 1975).

A variety of processes have been employed to improve the utilization of plant materials high in lignocellulose. These vary in degree of complexity and effectiveness, and they include soaking, fine grinding, irradiation with high-energy electrons, and chemical degradation by such agents as alkali, mineral acids, and sulfite. Presently chemical treatment yields the most nutritious end-product at the lowest cost. Nevertheless, the chemical methods are expensive in terms of fossil energy and require much water in rinsing. Donefer *et al.* (1969) observed that the improvement of the nutritive value of straw is directly related to the concentration of NaOH employed until the optimal level of 8 to 10 gm of NaOH per 100 gm of straw was reached at atmospheric pressure. At pressures above that of the atmosphere, less NaOH resulted in the same degree of improvement. As an alternative means of utilizing directly hill-land lignocellulose by ruminants, the feasibility of chemical treatment in the future will depend on monetary and/or energetic economics.

Use of Wild Herbivores

Some difficult-to-manage hill lands might be more productive as habitats for wild herbivores than for domesticated ruminants. For example, under certain ecological conditions in Scotland the red deer produces more meat per unit of land area than do domesticated ruminants (Kay, 1970). Moreover, deer yield considerably more lean meat per unit of carcass than do sheep and cattle (Blaxter *et al.*, 1974). Although there are many problems requiring research, a farming enterprise based on wild herbivores may be practiced at various levels of intensivity, depending on the conditions.

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DISCUSSION

R. Blaser (Virginia, USA). The suggestion is often made in grazing pastures to maintain the animal or let it lose weight. This is said to be desirable because then the animal will make very sharp compensatory gains. I have always doubted that philosophy and I should like to have you comment on whether such an animal does really compensate from the standpoint of the total energy budget.

Reid. We need to examine that problem from the standpoint, first of all, of the period of compensation—the period of so-called compensatory growth. We had a graduate student from New Zealand, Dr. Kenneth Drew, who carried out an extensive experiment on this subject with sheep. He observed that animals that had been deprived so as to lose approximately 30% of their original body weight, then re-fed to reach a given body weight, were found, after the re-feeding began, to be more efficient in their use of metabolizable calories than their mates which had been fed steadily to the same final body weight. Now, the ringer is, that when he took into account the total period, including the reduction in weight and the realimentation, it was less efficient than it was for the sheep kept in continuous positive energy balance because of the higher maintenance cost; the sheep had to be maintained during the period when they were losing body energy as well as during the compensatory growth period.

Blaser. How great was the difference?

Reid. The proportions of the metabolizable energy (ME) ingested above maintenance that were retained were 43% for the continuously fed animals and 57% during realimentation, for those which were realimented after the sub-maintenance feeding period. The maintenance requirements were 90 and 89 kcal/weight raised to 0.75 power/day, respectively. The amounts of feed (kg)/gain (kg) to a body weight of 50 kg were 5.6 and 7.2 for the sheep which were continuously fed and those which were deprived for 10 weeks and then re-fed, respectively.

K. O'Connor (New Zealand). If the cost of the feed supply for the two different phases were entirely different, doesn't that complicate the matter?

Reid. Yes, I agree. The efficiency value does not include economics. Also, if the feed could be supplied by an area which is difficult to manage, cannot be easily harvested, or might be expensive of energy and money, etc. to intensify, I agree the trade-offs could make it more economically feasible for animals to go through the two phases.

A. W. Pantall, (New Zealand). That would help to determine the meaning of your comment on alternative uses of hill land, e.g., breaking ligno-cellulose bonds by chemical means and use of wild herbivores on areas difficult to manage.

R. Shirley (Florida, USA). You have given an excellent talk about energy and since these animals need protein also, I wonder if some of this energy possibly might be turned into the production of protein in the presence of non-protein nitrogen.

Reid. Yes. What Dr. Shirley is asking is whether some of the excess energy taken in, for example in the presence of non-protein nitrogen such as urea, may be put into the protein cycle. That is certainly true. Even the circulating urea and other non-protein nitrogen return to the rumen via the saliva. Unfortunately, under many situations such as those of grazing hill lands or swards in the tropics—almost any situation in which a high forage diet is ingested—and in which the use of non-protein nitrogen would have a great value if it were utilized, there is not sufficient highly available energy present in these cellulosic materials to provide the means for ruminal bacteria to utilize the non-protein nitrogen effectively. There is an FAO report on non-protein nitrogen prepared several years ago by Ian McDonald and J. K. Loosli that lays out this problem and those conditions under which non-protein nitrogen can be effective and economical and those in which it is not. Thus, in the tropics and on hillsides where a lot of grass is grazed, the effectiveness of non-protein nitrogen is very low despite its potential in the presence of highly available energy sources.

G. A. Jung (Pennsylvania, USA). I would like to clarify that last point, Dr. Reid. Don't you really mean tropical or sub-tropical species of grasses? If you were to go to higher elevations in the tropics and switched to temperate species, wouldn't it improve?

Reid. Yes, at least to some degree. For example, in situations in which plants high in soluble carbohydrates can be grown, at least some utilization of non-protein nitrogen would be expected. A late-maturing perennial ryegrass, one of the magnificent developments of the Welsh Plant Breeding Station, is a grass which is quite high in soluble carbohydrates.

R. L. Reid (West Virginia, USA). I remember some of your remarks that the digestive efficiency of some of the animals—the alpaca for example—adapted to high country is considerably higher than that of conventional ruminants. Is this correct? Is there more

work in the literature on this relationship or on the increased efficiency for animals of high elevations? Perhaps there is someone else who would comment on this.

Reid. In a number of trials in which Saul Fernandez Baca in Peru compared alpaca and sheep fed the same diets, the digestibility by the alpaca was decidedly higher. These data, however, have been challenged by some people on the basis that the level of input might have been different. Now, the level of intake does affect digestibility by herbivores, but this depends upon the kind of diet. As the level of intake increases, the digestibility of mixed concentrate-forage diets or of pelleted, finely ground forages decreases. On most forages in long or chopped form, the intake is not great enough to depress digestibility. It seems possible that the digestibility of some of the improved forages which are high in soluble carbohydrates and which are ingested in large quantity might be depressed somewhat. Since some of the forages fed to the alpaca and sheep were coarse and fibrous, it would appear unlikely that the level of intake affected digestibility differently in the two species. I should mention that alpaca and llama are now commonly found at high altitudes, but at the time of the Spanish conquest in about 1530 AD, they were found at sea level in Peru. There have been comparisons made between other ruminants. For example, the water buffalo (*Bos bubalis*) has been compared with *Bos taurus*, such as Holstein cattle, fed the same forage materials. As an average for nine different forages, a difference in digestive efficiency of about 10% in favor of the water buffaloes was observed. Perhaps some of the people who are here from India or Pakistan are familiar with other similar comparisons.

J. Eadie (Scotland). Before we rush to arrive at conclusions arising from differences in efficiencies, we ought to address ourselves, I think, to the question of voluntary intake of these animals; their capacity to consume the forages in the environments in which they live would seem to be to be probably a much more important determinant of their usefulness as pasture animals, than just efficiency.

Reid. Yes, I quite agree. Each animal has its own natural diet and the important thing is how much of it a given animal will consume in the habitat for which the animal is adapted.

85.
Land Rehabilitation in the Upper Solo River Area

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The Indonesian archipelago has a land area of approximately 2 million sq km with a population approaching 135 million. The average population density is 70 per sq km. The most fertile island is Java, comprising 128 428 sq km (6.6% of total area), inhabited by about 80 million (60% of total population). It has a population density of 625 per sq km. Over 60% of Java's population is dependent on agriculture for livelihood, with an average landholding of 0.1–0.2 ha per farmer. The average per capita income is about $60 per year.

Unemployment in Indonesia exceeds 13% (Djojohadikusumo, 1976), not including disguised unemployment which exists to a significant extent on Java due to the seasonal type of employment in agriculture. In Indonesia about 20 million ha, or 10% of the total area, are considered wastelands or seriously eroded soils. Java is worse off: wastelands amount to 4 million ha or more than 30% of the land (Sumintawikarta, 1975).

Recently a program was launched in Indonesia to rehabilitate 100 000 ha of eroded soils annually. Starting this year, this program has been stepped up, comprising 400 000 ha with an annual budget exceeding $40 million.

Land rehabilitation in the Upper Solo River area of central Java is one of these efforts.

THE PROBLEM

The Upper Solo River area covers 10 252 sq km (1 025 200 ha), of which more than 2 500 sq km (250 000 ha) can be classified as seriously eroded. A general picture of the area is given in Table 1. One-third of the area consists of level farmland and two-thirds of hilly and mountainous lands with slopes of varying steepness and with varying degrees of erosion hazard.

The present land use is given in Table 2. In general, about one-third is devoted to rice, one-fifth to home gardens clustered around villages, and one-third to

TABLE 1. Land classes based on topography in the Upper Solo River area, Indonesia

Topographic Land Class	Area (ha)	Percentage
Level Lowlands	341 820	33.4
Kendeng and Karanggede hills	129 760	12.6
Volcanic lower slopes	240 360	23.4
Volcanic middle slopes	101 520	9.9
Volcanic upper slopes	50 220	4.9
Southern mountains	161 520	15.8
Total	1 025 200	100.0

Source: Directorate of Land Rehabilitation and Reforestation.

TABLE 2. Land use classes in the Upper Solo River area, Indonesia

Land Use	Area (ha)	Percentage
Ricefield (irrigated)	245 160	23.9
Ricefield (rainfed)	65 920	6.4
Home gardens	195 210	19.0
Dry farmland	294 730	28.7
Estates	5 760	0.6
Forest	142 590	13.9
Other	75 830	7.4
Total	1 025 200	99.9 (100)

Source: Directorate of Land Rehabilitation and Reforestation.

dry farmland. Map 1 shows the two catchments of the Upper Solo River area: the Bengawan Solo and the Bengawan Madiun, the former almost twice as large as the latter, as shown in Table 3.

The basic problem is a rapidly expanding population (mean density 700 per sq km) with few employment opportunities. Population pressure causes land hunger, resulting in gradual deforestation of upland areas. Unwise use of these hill lands, due to the farmer's ignorance and lack of capital, leaves behind heavily eroded soils. The effects are increased runoff causing floods, siltation, and reduction of soil fertility. A study revealed (McComb, 1971) that during the rainy season of 1970–71, more than 8 million MT of soil were carried past the city of Surakarta, which in various parts of the area means a soil loss of 3 to 4 cm per year. Economic loss caused by reduction in crop production amounts to $25 million annually (McComb, 1973).

TABLE 3. Catchment areas of the Upper Solo River, Indonesia

Branch	Catchment Area (sq km) Residency Solo	Residency Madiun	Total
Bengawan Solo	5 763	837	6 600
Kali Madiun	192	3 460	3 652
Total Area	5 955	4 297	10 252

Source: Directorate of Land Rehabilitation and Reforestation.

Because of erosion, farm income is very low and subsistence farmers are numerous. In a study of 375 sample farms in a seriously eroded part of the area, the average gross annual value of all farm produce was $45 per family. The landless farmers had an annual income of less than $22.50 per family (McComb, 1973).

THE PROJECT

Starting July, 1973, a three-year land rehabilitation project was initiated by the Indonesian government with technical assistance from UNDP/FAO and financed jointly. The aim is twofold: to develop and demonstrate techniques of watershed management and upland development in selected parts of the Upper Solo River area; and to forward proposals and recommendations to the government of Indonesia regarding ways and means for the prevention and rehabilitation of similar situations occurring throughout Java.

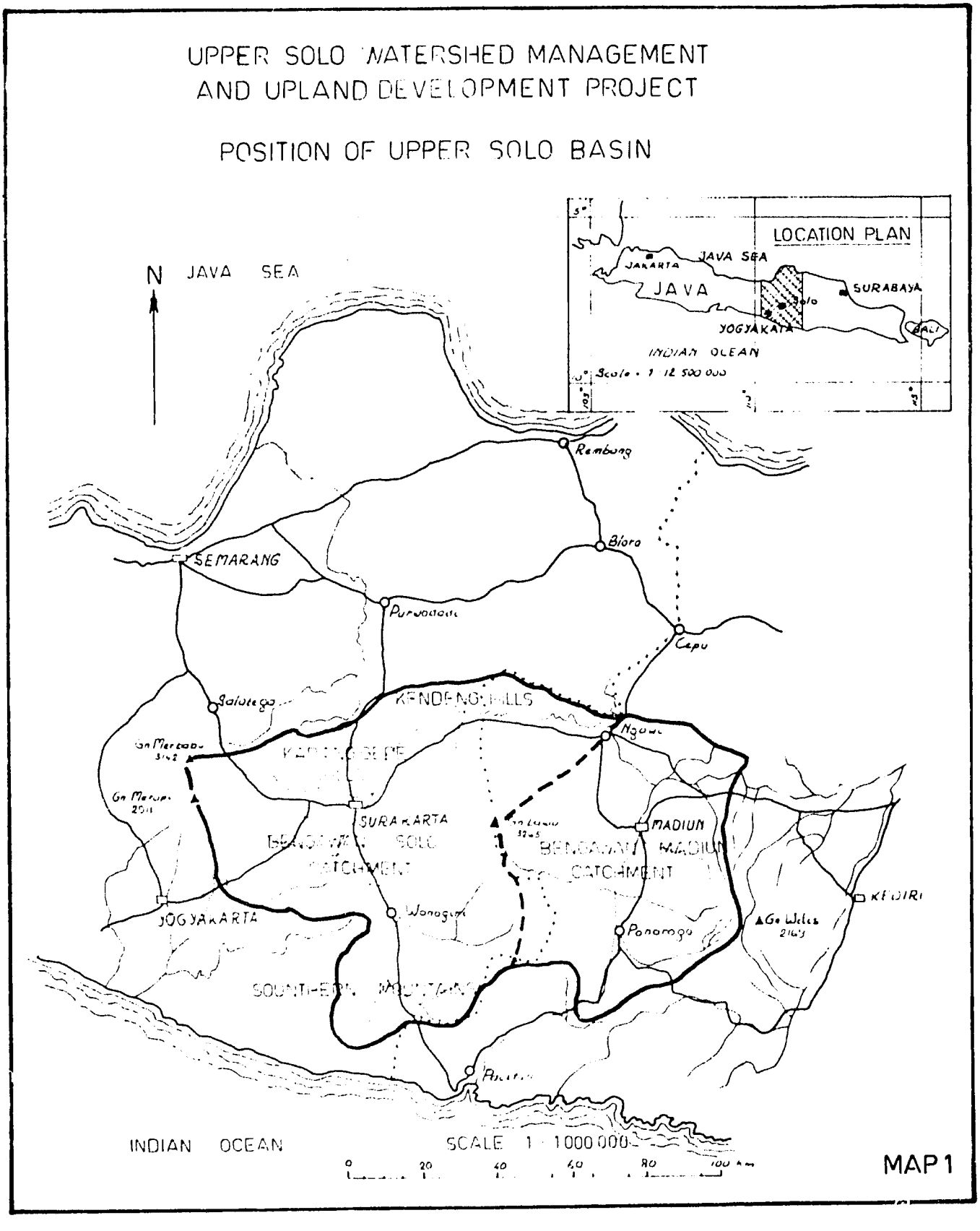
Previous efforts of reforestation and afforestation in Upper Solo dated back to 1970 in cooperation with the World Food Program (WFP). However, the land rehabilitation project with UNDP assistance is the first of its kind in which foreign and Indonesian experts work closely together for the duration of the project. Similar to the previous program, the food supply comes through WFP.

Four watersheds with a total area of 76 785 ha, including 1 685 ha comprising seven sample subwatersheds, have been chosen representing typical situations and range of problems of the Upper Solo River area. The above is given in Table 4, whereas Map 2 shows the location.

Land considered for rehabilitation is divided into two categories according to slope: land with slopes of less than 50%; and slopes of 50% and up.

Farmers are encouraged and persuaded to apply proper agricultural techniques in food-crop cultivation on slopes of less than 50%. Persuasive efforts are conducted to establish tree crops on land-holdings with 50% slope and up. Seriously eroded landholdings on slopes of less than 50% receive similar treatment. Grass cover with sufficient nutritive value for cattle and cultivation of cash crops are integrated in the program.

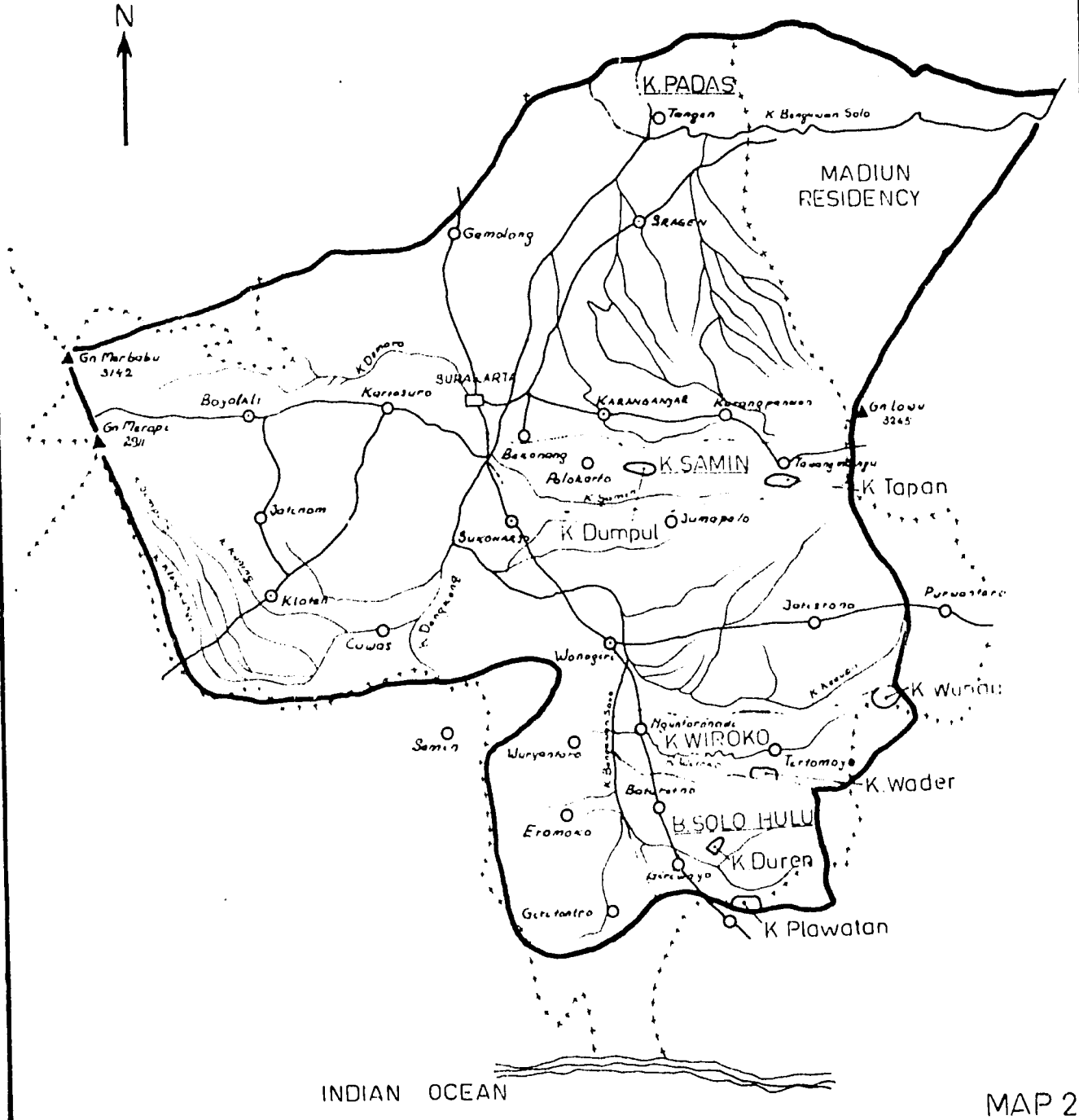
The multifaceted approach by the project to land rehabilitation is reflected in the six sections: soil conservation, hydrology, forestry, agronomy, watershed economy, and extension education.


UPPER SOLO WATERSHED MANAGEMENT
AND UPLAND DEVELOPMENT PROJECT
POSITION OF UPPER SOLO BASIN
LOCATION PLAN
JAKARTA
JAVA SEA
JAVA
SURABAYA
YOGYAKARTA
BALI
INDIAN OCEAN
N
JAVA SEA
Rembang
Blora
SEMARANG
Purwodadi
Cepu
Salatiga
KENDENG HILLS
Ngawi
SURAKARTA
MADIUN
JOGYAKARTA
Wonogiri
Ponorogo
KEDIRI
INDIAN OCEAN
SCALE 1 : 1 000 000
0 20 40 60 80 100 km
MAP 1

UPPER SOLO WATERSHED MANAGEMENT AND UPLAND DEVELOPMENT PROJECT

BENGAWAN SOLO RIVER BASIN LOCATION MAP OF WATERSHEDS

SCALE 1 : 500.000



MAP 2

TABLE 4. Representing watersheds with their sample sub-watersheds in the land rehabilitation project of the Upper Solo River Area, Indonesia

Name of Watershed and Sub-watershed	Area of Watershed (ha)	Area of Sub-watershed (ha)
Kali Padas	3 470	250
Kali Samin	26 595	
SWS Kali Dumpul		186
SWS Kali Tapan		222
Kali Wiroko	21 190	
SWS Kali Wader		330
SWS Kali Wungu		280
Upper Bengawan Solo	25 530	
SWS Kali Plawatan		210
SWS Kali Duren		207
Total	76 785	1 685

Source: Directorate of Land Rehabilitation and Reforestation.

The broad range of activities include:

(a) soil conservation by means of bench-terracing and construction of gully plugs and waterways;

(b) improvement of irrigation, construction of checkdams, measurement of water regime;

(c) reforestation and afforestation;

(d) guidance for proper agricultural techniques and home gardening;

(e) analysis of economic development inside and outside the subwatershed; and

(f) dissemination of improved techniques, and cadre forming.

In each sub-watershed, physical rehabilitation work is carried out by the local people and partially paid for in WFP rations. Labor inputs on physical development are, among others: Bench terracing, including waterways and gully plugs, consumes 1 100-1 300 man-days per ha on slopes of 10-20%, rising to 2 500 man-days on slopes approaching 50%. Forest plantations take 400 man-days per ha, plus 35 for maintenance. Construction of roads requires 900 man-days per ha.

What has been achieved?

The project terminated last June. It turned out that there are no easy answers to the problem of land rehabilitation and development. On the positive side, the following results can be noted: In treated sub-watersheds measurements have shown a decrease of 35% in surface runoff, while erosion has been checked up to 95%. Application of proper cultivation techniques has increased yields of foodcrops significantly. Construction of checkdams and diversion ditches is expected to enlarge the area of new ricefields up to 20%. Sample checks have revealed a more profitable cost/benefit ratio and increased internal rates of return (Soedarma, 1976).

On the other hand, the cost of physical land rehabilitation proved to be beyond he reach of the average farmer. Continuing and broadening rehabilitation efforts will require heavy subsidies.

Besides the physical aspects, there looms the danger of overpopulation on Java. Consequently, land-man ratio will be decreasing below the minimum carrying capacity. Transmigration has not been able to cope with the overpopulation problem. Population increase on Java is roughly 2 million a year, whereas in the past, transmigration through government channels proved capable of moving only an average of 25 000 people annually.

In conclusion, a collision course still prevails between man-made poverty by way of erosion and the need for a better quality of life through land rehabilitation and development.

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86.
Rehabilitation of the Lynx Creek Watershed Degraded by Past Mining Activities

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Surface mining in the Southwestern United States is becoming increasingly important in meeting this nation's mineral and energy needs. New mines are being opened and hundreds of ha are being added each year to the areas already disturbed by past mining activities. Although reclamation is presently becoming an integral part of many active mining operations, a great number of the old abandoned mining sites remain. They include open pits, tunnels and shafts, mill tailings ponds, and mine dumps. These remnants are active sources of sediment and toxic mineral pollution that affect the quality of streams and lakes and detract from the natural environment of many watersheds. In many instances, degradation of the watersheds has resulted in heavy concentration of sediment and toxic pollutants in the runoff and has disrupted the flow and quality of water in several of the few streams and lakes in the region.

The Lynx Creek watershed on the Prescott National Forest of Arizona (Fig. 1) (long 34° 27′; lat 1/2° 23′) is typical of many Southwestern watersheds degraded by past mining activities. Furthermore, it is located in a particularly scenic area and is one of the not-too-numerous areas of Arizona with water. Lynx Lake, with an area of 22 surface ha, is fed by the runoff from the Lynx Creek watershed. Recreation is the major land use. The lake was created by a dam built in 1963 by the Arizona Game and Fish Department. The aim was to provide the area residents with a trout fisheries lake. Aquatic life and recreational potential of the lake is greatly reduced by the water pollution problem in the watershed.

The Lynx Creek watershed was the scene of intense mineral exploration and minimg activity during the first third of the 20th century. The major stream channels were dredged for gold. Numerous productive prospects were developed throughout the watershed, the largest being the Sheldon Mine which included miles of underground tunnels, a processing mill, and a transport system. This operation left a large dump of mining waste and a tailings pond. The problem of rehabilitating this watershed is of particular importance to the people of the state. This paper discusses the results of a cooperative effort undertaken in the spring of 1974 by SEAM (Surface Environment and Mining), a USDA Forest Service Program to research, develop, and apply technology that will help maintain a quality environment and other surface values in the face of mining activities, and by the School of Renewable Natural Resources, University of Arizona, to analyze and remedy the impacts of the past mining operations within the Lynx Creek watershed.

WATERSHED ENVIRONMENT

Geography

The Lynx Creek watershed (Fig. 1), with an area of about 7 300 ha, is located on the Prescott National Forest about 8 km south of Prescott, Arizona. The watershed is mostly within the ponderosa pine ecosystem. The entire watershed is in a mountainous region, with creekbeds lying within the sharp ravines

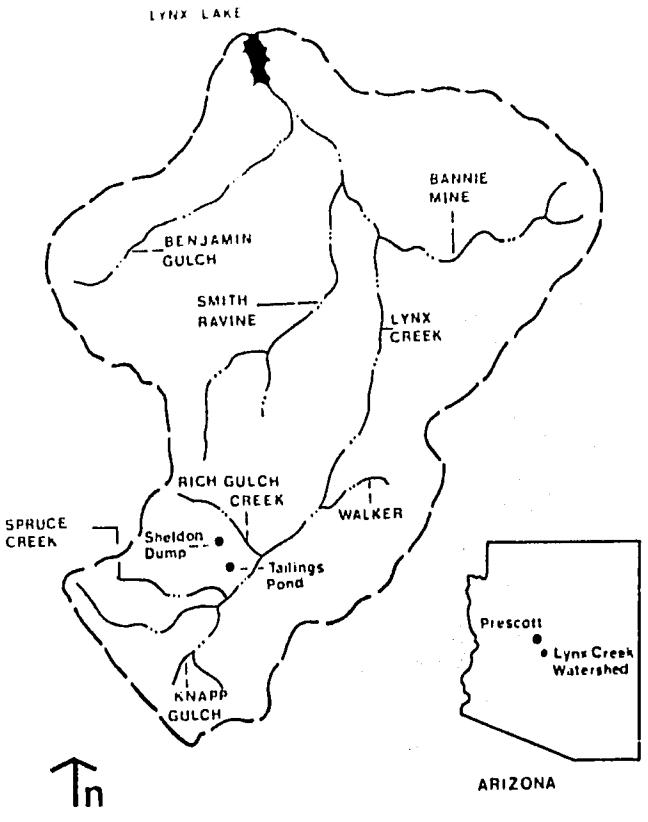

Figure 1. Lynx Creek watershed.

bounded by slopes averaging 119%. The head of the watershed is on Mount Davis (2 423 m), spreading northward from Mount Davis, falling gradually from this elevation to Lynx Lake, an elevation of 1 675 m. Mountain ridges on the east and west sites give the watershed a well-defined and closed surface-water system. Lynx Creek begins at an elevation of about 2 200 m and after a 13 km course, drains into Lynx Lake. Major tributaries to Lynx Creek are shown in Fig. 1. Basalt, granite, and schist compromise major portions of the bedrock. The watershed is transected by the Chaparral Fault. Wells drilled into bedrock experience excellent water yields, indicating widespread fracturing of the bedrock in the area.

Climate

The climate in this general region is classified as semi-arid with abundant precipitation occurring only from July through mid-September. During this period when moist tropical winds from the Gulf of Mexico dominate the area, thunderstorms develop almost every afternoon over the nearby mountains. During the rest of the growing season, precipitation is deficient. A rough estimate of the annual precipitation, as an average for the watershed, is about 650 mm. About 40% of the annual precipitation is in the form of snow.

Soils

The soils in this watershed are from a granite and schist origin with slopes ranging from 30 to 60%. These soils are weakly developed and shallow. They contain variable amounts of gravel, cobble, stone, and rock outcrop on the surface and throughout the profile. The texture is sandy loam to clay loam in the upper horizons and mostly clay in the lower horizons.

Vegetation

The dominant overstory vegetation is ponderosa pine (*Pinus ponderosa*), with Arizona white oak (*Quercus arezonica*), emory oak (*Quercus emoryi*), turbinella oak (*Quercus turbinella*), mountain mahogany (*Cercocarpus paucidentatus*), and black walnut (*Juglans major*) in the understory. Douglas fir (*Pseudotsuga taxifolia*), white fir (*Abies concolor*), and quaking aspen (*Populus tremuloides*) are also scattered in the overstory. Grasses common to the ponderosa pine community, as well as weeping lovegrass (*Eragrotis curvula*), a species introduced to the area, are found throughout the watershed (Table 1).

Abandoned Mine Spoils

There are numerous mining claims scattered throughout the watershed. While few of them are active, many have been active at some point within the past fifty years. Surface disturbances such as slides, tailings ponds, dumps, and mine shafts give the natural landscape scars which are characteristic of these short-term mining operations. The Sheldon Mine complex seems to be the major source of sediment and toxic mineral pollutants into the lake.

The majority of solids in the Sheldon Mine tailings and dump consist of quartz feldspar, pyrite, sericite, and limonite. Assay of the tailings and dump (Table 2) shows high amounts of heavy metals. Chemical analysis of the leachate (Table 3) also indicates high amounts of Cu, Pb, Zn, Fe, and SO_4.

TABLE 1. Vegetation types in the Lynx Creek Watershed

Vegetation Type	Hectares	Percent of Total
Ponderosa pine	3 294	45
Chaparral	2 442	33
Pinyon-juniper	623	9
Open grassland	221	3
Mixed conifer	724	10
	7 304	100

TABLE 2. Assay of Sheldon Mine tailings and dump

Sample Source	Cu	Pb	Zn	Fe
		Percent		
Dump	0.136	0.320	0.20	6.4
Dump leached residue	0.116	0.320	0.17	6.2
Tailings	0.088	0.086	0.22	4.2
Tailings leached residue	0.016	0.086	0.14	2.5

TABLE 3. Representative chemical analysis of leachate from the Sheldon Mine dump and tailings

Sample Source	pH	Total Solids	Cu	Pb	Zn	Fe	SO_4
					ppm		
Dump	3.2	22 500	240	3	600	3 200	13 500
Tailings	2.2	77 400	820	5	2 390	13 800	45 100

Particle size distribution in the samples from the tailings (Table 4) indicates that about 62% of the particles are of medium sand size. The tailings have a very high water-retention capacity and are water saturated at a depth of ⅔ to 1 m from the surface.

TABLE 4. Particle size distribution in the Sheldon Mine tailings

Size (mm)	Weight (gms)	Percent of Total
1.98	39.0	10
0.99	61.0	14
0.495	149.0	36
0.246	106.5	26
0.124	38.5	9
0.061	21.5	5

Hydrology

The watershed drains into the lake through Lynx Creek. Stream flows are high during the spring snow-melt and during the high rainfall period of July and August. Estimates of the annual water yield from the watershed vary from 5.08×10^5 cubic meters for the years of high precipitation (Williams, 1968). Average annual water yield is estimated at 6.96×10^5 cubic m. Erosion and sediment rates are quite high. Williams (1968) estimated that about 2900 cubic m of sediment is washed down into Lynx Lake each year, mostly during the peak flow periods.

Snow can accumulate to a depth of several feet and remain well into early spring. Springs dot the watershed, but most are of intermittent nature, flowing only after the periods of good precipitation. These springs contribute only a small portion of surface runoff.

Groundwater exists in small pockets of shallow alluvium deposits. Deep groundwater is not expected to have a significant effect on the stream and lake.

Water Quality

Water quality in Lynx Lake has become a limiting factor in the lake's potential for aquatic and recreational use. Chemical analysis of the water samples from the lake (Table 5) indicates the presence of Cu, Zn, Fe, and SO_4. The horizontal distribution of the pollutants within the lake showed a decreasing trend from the point of entry of the creek, to the lowest levels near the dam.

Higher acidity (low pH) of water can bring heavy minerals into solution and, therefore, is a good indicator of water quality. Water pH measurements were taken on hand-picked samples from Lynx Creek and its tributaries (Fig. 2). The samples from the streams below the mine spoils had high water acidity and the Sheldon Mine tailings pond and dump were found to be substantial pollutant sources (Table 6). Follete and Wilson (1969) reported that the tributary above the Sheldon Mine tailings pond contributed less than 3.2 gm/day each of Cu, Fe, and Zn. However, below the tailings pond the tributary water was carrying 100 gm/day of Zn. Their calculations

TABLE 5. Water quality in the Lynx Lake with increasing depth

Depth (M)	TDS	Cu	Fe	Sulfates	Zn
			ppm		
0.00	198	0.12	0.03	168	0.04
1.52	197	0.12	0.04	158	0.04
3.05	193	0.11	0.03	170	0.05
4.57	192	0.10	0.01	162	0.05
6.10	189	0.10	0.04	164	0.08
7.62	184	0.13	0.04	157	0.06
9.14	185	0.09	0.08	162	0.08
10.67	188	0.09	0.08	157	0.07
12.19	191	0.34	0.03	148	0.06
13.72	191	0.16	0.03	145	0.07
15.24	192	0.10	0.06	147	0.05
16.76	188	0.16	0.04	142	0.16
Average	191	0.14	0.08	157	0.07

were based on the analysis of the samples taken on April 15, 1969. The water pH (Table 7) increases gradually from upstream, just below the mine tailings, to downstream before Lynx Creek enters the lake. Any rise in water pH causes precipitation of some soluble Cu, Fe, and Zn. Therefore, water quality in the creek is somewhat improved as it enters the

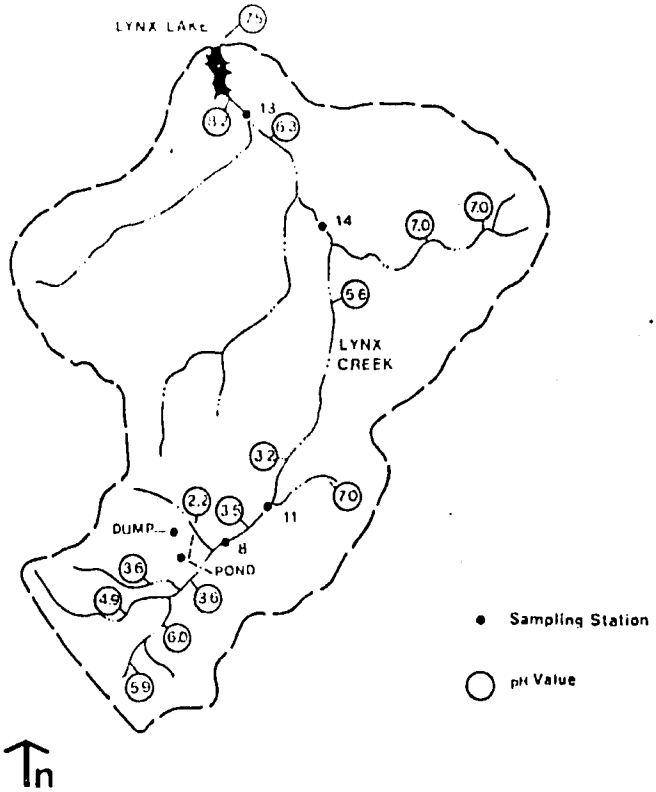

Figure 2. Lynx Creek watershed.

TABLE 6 Water quality of the Lynx Creek watershed

(a) Lynx Creek above confluence with Spruce Creek				
	Date of Sampling			
Parameter	11/74	8/74	4/75	9/74
pH	6.2	5.7		6.1
Cu mg/l	0.1	0.65	0.1	0.29
Zn	0.6	0.15		
Fe		0.22	0.1	0.33
S.S.	153	110	110	

(b) Lynx Creek below confluence with Spruce Creek [illegible] Sheldon Tailings pond					
	11/74	8/74	4/75	9/74	10/74
pH	6.4	[illegible]		4.0	
Cu mg/l	1.2	10.3	1.10		[illegible]
Zn	10.5	[illegible]			
Fe		2.0	0.5	0.13	[illegible]
S.S.	556	1170	300		60

(c) Lynx Creek below Sheldon Tailings pond					
	11/74	8/74	9/74	10/74	8/74
pH	7.6	[illegible]	5.0		7.9
Cu mg/l	0.1	[illegible]	[illegible]	[illegible]	0.01
Zn	0.2	0.1			
Fe		[illegible]	1.00	[illegible]	
S.S.	[illegible]	600		[illegible]	[illegible]

TABLE 7. Changes in quality of Lynx Creek watershed with increased distance and dilution

[illegible]	pH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			ppm			
8	3.0	5.0	5.8	9.0	320	0.6
11	2.9	3.7	5.3	9.6	416	0.8
14	5.8	0.01	0.25	0.47	55	1.7
13	6.4	0.01	1.4	0.06	43	3.3

lake, however, the samples taken from the creek at the inlet to the lake showed appreciable concentrations of Cu, Fe, and Zn at levels indicating the entry of these metals into the lake. This is further supported by the concentration levels of Cu, Fe, and Zn in the lake.

REHABILITATION

The Sheldon Mine complex consists of tailings pond and a dump. The tailings pond is about 1.2 ha of material derived from the later stages of the ore refining process. The material is composed of

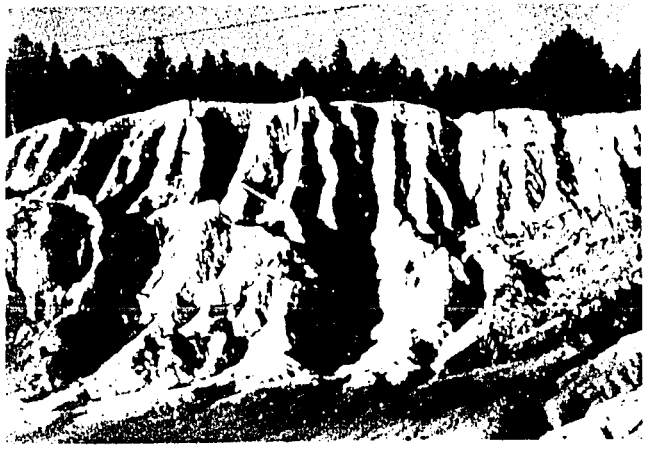

Figure 3. Tailings pond before rehabilitation

fine particulate matter of high moisture retention capacity. The face of the tailings was badly eroded (Fig. 3).

The dump consists of approximately 2 ha of coarser material derived from the early stages of the refinement process. It had steeper slopes (about 100% to 119%) showing mostly sheet erosion (Fig. 4).

Figure 4. Sheldon dump, before rehabilitation.

The tailings pond was rehabilitated during June, 1975, and the dump during July, 1976. The rehabilitation of these two major sources of pollutants was carried out in three phases.

Regrading

The tailings and dump were regraded to modify or eliminate unstable slopes. The landscape was designed to blend in well with the surrounding landscape, to facilitate on-site conservation of precipitation, and to reduce water erosion potential. Surface runoff from the catchment areas above the tailings pond, as well as from the contributing areas above the dump, was diverted off the recontoured sites to reduce the erosion problems. On the tailings pond, the gullies were backfilled and compacted. Contour terraces were used as soil conservation measures to reduce the steepness and length of slopes on both sites.

Revegetation

Regraded sites were revegetated by planting a mixture of introduced and native plant species (Table 8). To facilitate an early establishment of effective vegetative cover, regraded areas were limed at a rate of 75 000 kg/ha. The lime was added to improve soil pH in the upper 15 cm of the regraded material. This would also provide a buffer zone for the upward movement of low pH water from the saturated subsoil in the tailings pond. A 25 cm layer of top soil was added on top of the limed surface and compacted by a bulldozer. The dozer was walked up and down the slope to create small rills across the slope with the dozer tracks.

The area was hydroseeded with seeds (48 kg/ha) placed in a mixture of Silvatiber R at a rate of 1 500 kg/ha and Petroset SB-R soil binder at a rate of 1 000 /ha.

The seed mixture of grasses and legumes was selected in consultation with the Prescott National Forest personnel. Plant species adaptable to this 2 000 m elevation with about 65 cm of annual precipitation were selected.

A mixture of native trees and shrubs had been planted on the tailings pond during July, 1976. The seedlings were hand-planted at the start of rainfall season. A similar mixture of native trees and shrubs were planted on the dump during July, 1977. Dead plants will be replaced during the following year to insure effective revegetation and successful rehabilitation of these sites.

TABLE 8. Seed mixture for revegetation

Common Name	Scientific Name	Percent
Alfalfa Cf. ranger	*Medicago sativa*	5.0
Vetch, common	*Vicia sativa*	37.5
Black medic	*Medicago lupulina*	2.5
Orchardgrass	*Dactylis glomerata*	2.5
Wheatgrass, pubescent	*Agropyron trichophorum*	32.5
Ryegrass, Cf. perennial	*Lolium multiflorum*	12.5
Weeping lovegrass	*Eragrostis curvula*	2.5
Hard fescue	*Festuca ovina var durisucula*	2.5
Lehman's lovegrass	*Eragrostis lehmanniana*	2.5

Erosion Control

Excessive runoff may cause erosion problems on the regraded sites that are devoid of vegetative cover. To alleviate this potential hazard, off-site runoff is diverted through a peripheral drainage swale system to existing stream channels below each site. On-site runoff is retained and controlled by terracing the slopes. Each site has been hydromulched and top soil dressed to increase infiltration rates into the ground and to reduce erosion potential.

RESULTS AND DISCUSSION

The results of rehabilitation efforts on the Sheldon Mine tailings pond and dump have been encouraging. An excellent vegetation cover (Fig. 5) was established within four-five weeks of seeding on the tailings. Runoff and sediment control on the tailings and dump appear effective, and it is being monitored. Field analysis of hand catch water samples with a Hach Field Kit (Hach Chemical Co., Ames, Iowa, USA) indicated a significant improvement in the water quality of runoff from the tailings.

Figure 5. Tailings pond, after rehabilitation.

Soil conservation measures such as contour terracing on the face of slopes, diversion ditches, and contour furrowing before seeding are proving effective for erosion control. Some problems did occur in the diversion ditch on the tailings. Proper maintenance measures were taken in the fall of 1975.

The success of the rehabilitation measures undertaken on the Lynx Creek watershed will be estimated through monitoring of water quality and the establishment of a continued maintenance program to insure the effectiveness of vegetative establishment.

Other sources of pollution with the watershed must receive an equal amount of attention to restore the water quality and recreational potential of the Lynx Lake.

The methodology and technological experience gained from this project will provide valuable information for reclaiming abandoned mining sites within the ponderosa pine ecosystem.

ACKNOWLEDGMENT

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DISCUSSION

J. Phelan (Virginia, USA). What was the cost of this treatment per hectare?

Verma. The cost of treatment, because it was a demonstration project and we didn't want to take any chances, was as expensive as it usually is. Cost for the tailings pond was about $18,000/ha and cost on the mine dump about $13,000/ha.

R. Singh (West Virginia, USA). I wanted to check on the chemical analysis you showed for tailings material. Is that a total analysis or some other extractable? What did you use for it? You had quite a high value for zinc and copper.

Verma. This was an assay analysis done by the U.S. Bureau of Mines Lab in Salt Lake City and I am not sure about the procedure.

T. Bradshaw (Liverpool, England). Was the tree planting done into just the same 20 cm of topsoil? If so, do you really think those trees will survive? Or was it done into larger, deeper pockets.

Verma. No, the tree planting or the seedling planting wasn't done in 20 cm of topsoil. The pits were dug about 65 cm deep and they were filled with topsoil and limed and then the seedlings were planted so that they would have about 65 cm to 1 m of medium to grow in.

87.

Revegetation of Steep Outer Slopes for Erosion Control In Strip-Mined Areas*

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Surface coal mining in mountainous areas changes the original terrain into two main configurations: level bench areas in the same plane as the mined coal layers, and outer slopes, below the level bench areas and often steeper than the original topography. Stabilizing the outer slopes against erosion continues to be one of the complex problems associated with the reclamation of surface mined land. Stabilizing the spoil material of the man-made outer slopes is difficult. These problem areas should be revegetated immediately after mining operations are completed. Otherwise, the outer slopes are susceptible to sheet and rill erosion, which contribute to potential pollution hazards. Also, erosion destroys emerging vegetation and leaves permanent deep gullies, and downstream sediment. In the past, laws governing surface mining were inadequate and resulted in neglect of these disturbed land areas (Fig. 1). Today, almost all states have laws that require the restoration of disturbed land after mining operations are completed.

Figure 1. An eroded area that needs vegetation.

* [illegible] West Virginia and funded in part by the U.S. Environmental Protection Agency.

** Strip Mine Foreman, Maryland Bureau of Mines, Westernport.

Steep outer slopes are formed when the earth materials are pushed from the bench and allowed to reach a natural angle of repose. During the process, the larger particle-size material will move further down slope than will the finer materials. The particle size distribution may cause soil water deficiencies and limit the success of revegetation on the lower portion of the slopes. This problem could be alleviated if somehow the large material were pushed from the level bench area first and then the finer materials used as a surface cover over the entire slope area. This procedure would afford a surface with fairly good water-holding characteristics (Jones *et al.*, 1973).

Establishing permanent vegetation is the only practical way to stabilize steep outer slopes, and reclamation is not complete until these areas have been revegetated. Due to the nature of the slopes, we had to devise techniques for holding amendments and seeds in place during germination and early seedling development. Woodruff *et al.* successfully used a seed bed of lateral-groove technique to improve establish vegetation on steep slopes of highway cuts. This seemed to be an excellent procedure to adapt to outer slopes of strip mine areas. The construction of lateral grooves would also promote water retention on the slopes, which is extremely important for the establishment and maintenance of vegetative cover.

Chemical analyses of the spoil material are needed to determine the amendments needed for optimum plant growth. Plant species should be adapted to the environmental conditions and should develop rapid and penetrating root systems that will anchor the unstable spoil material quickly and effectively. The purpose of our research was to determine the feasibility of using the lateral groove technique on several different surface mined sites and to test the performance of several plant species grown on differentially amended spoil materials.

METHODS

West Virginia

In 1971 two mountain sites in Appalachia (southern West Virginia) were selected for evaluating the lateral-groove technique. The White Oak Mountain site was at 760 m elevation with spoil material at

pH of 6.6 to 4.0. The Bolt Mountain site was at 1,160 to 1,220 m elevation with a spoil pH of 2.9. The slope percentage at each location was not accurately determined but exceeded 65.

Reconstructed essentially lateral grooves (standard terraces) with hand tools on acid plots on the steep outer slopes at each site. The 10 cm grooves were spaced about 60 cm apart on the contour of the slope and parallel with the level benches. The upper half of the slope was laterally grooved while the lower half was not grooved. The lower half was covered the control. A schematic diagram of this slope shown in Fig. 2, was used with seedings for vegetative cover.

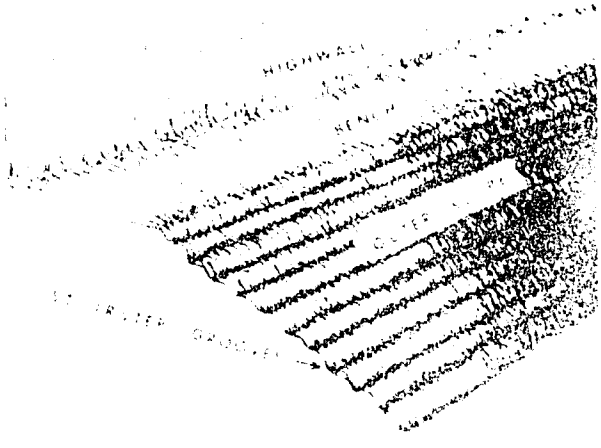

Figure 2. Lateral groove technique utilized on steep outer slopes.

At each location we used a split-plot design with two applications. Four phosphate treatments comprised the main plots. At White Oak Mountain 4.6 and 9.2 MT/ha of rock phosphate or 45.2 kg/ha P_2O_5 superphosphate was used. At Bolt Mountain 4.6 and 9.2 or 13.7 MT/ha of rock phosphate or 22.6 kg/ha of P_2O_5 superphosphate was used. The main plots were divided into subplots that were seeded or planted to legumes either by direct seeding or by transplanting greenhouse-grown seedlings spaced about 45 cm apart on the terraces. Empire birdsfoot trefoil (*Lotus corniculatus*) was grown at White Oak Mountain, and both trefoil and Penngift crownvetch (*Coronilla varia*) were grown at Bolt Mountain. Both experiments were overseeded with weeping lovegrass (*Eragrostis curvula*) for quick cover and stabilization.

On the extremely acid Bolt Mountain spoil, 11.4 MT/ha of dolomitic limestone was uniformly applied on all plots. At White Oak Mountain 4.6 MT/ha of dolomitic limestone was used. Other amendment applications, at each location, included 22 kg/ha N, 167 kg/ha P_2O_5 and 11 kg/ha molybdenum. A straw mulch was utilized to aid seed germination and early seedling development.

Western Maryland

In 1973 an outer slope site with a southern exposure in Western Maryland (George's Creek area) was selected for revegetation. The site was at 460 m elevation and was characterized by spoil material with pH of 3.4. The experimental area had about 40% slope that was subjected to severe sheet erosion. On the face of the outer slope, we used the steep-step terrace technique (lateral grooves) on the upper half of the slope face. The whole outer slope received one of two amendments at 6.6 and 9.2 MT/ha of dolomitic limestone and phosphate rock (respectively) and 171 and 114 kg/ha of N and P_2O_5 respectively. Variable treatments were different plant species: Tufcote Bermudagrass (*Cynodon dactylon* [illegible]), [illegible] of Blackwell switchgrass (*Panicum virgatum* [illegible]), [illegible] tall fescue (*Festuca arundinacea* [illegible]), [illegible] crownvetch. All plant species were seeded except for Tufcote Bermudagrass, which was established by planting sprigs [illegible] hand propelled [illegible] machine.

[illegible] 1974 an outer slope composed of exposed [illegible] spoil pile on Western Maryland [illegible] was prepared for revegetation by a phase [illegible] procedure similar to that used in West Virginia and at the other Western Maryland location. This site was at 700 m elevation with a northern exposure. The varieties at this location were plant species that subjective were to screen plant species for their adaptability to mine spoil at different locations with various soil amendments.

The strip-mined area at Frostburg was laterally grooved before applying amendments and seeding. Tufcote Bermudagrass was established by sod planting. Other plant species (weeping lovegrass, KY-31 tall fescue, birdsfoot trefoil, and KY-31 tall fescue-crownvetch mixture) were all directly seeded. Uniform amendments applied were 6.6 and 11.3 MT/ha of dolomitic limestone and phosphate rock, respectively, and 228 and 171 kg/ha of N and P_2O_5 respectively. Tufcote Bermudagrass (sprigged), weeping lovegrass, KY-31 tall fescue, birdsfoot trefoil mixture, and crownvetch-red fescue mixture were seeded and Tufcote Bermudagrass was sprigged in

RESULTS

West Virginia

Germination and plant development of weeping lovegrass and birdsfoot trefoil on the direct seeded plots at White Oak Mountain were excellent. The transplanted birdsfoot trefoil seedlings also made excellent growth. Plants established in the grooves afforded protection to the steep outer slopes and full vegetative cover was obtained by midsummer of the seeding year (Fig. 3). Thus, excellent erosion

Figure 3. Excellent cover of weeping love grass and birdsfoot trefoil on a steep outer slope.

[illegible] grooved half of the slope [illegible] well established until the second or third week.

Complete ground cover was obtained on both experiments at Bolt Mountain. However, weeping lovegrass contributed more than 75% of the cover during the seeding year. The transplanted crownvetch plants made satisfactory growth on all the variable fertility treatments. The initial growth from direct seeding of the selected legumes was encouraging.

Dry-matter yield data from clipped samples harvested in 1971 and 1972 at both locations are given in Table 1. Dry-matter yields from the direct seeded plots on White Oak Mountain indicated that the phosphate rock treatment gave yields that were closely comparable with those of the superphosphate treatment, 4545 to 4832 kg/ha, respectively. In 1972, the average yield of phosphate rock treated plots compared to superphosphate plots was 7219 to 7722 kg/ha, respectively. A statistical analysis of the data showed that yield differences due to treatment effects were not significant. In 1971, yield samples were separated to determine the legume-grass ratio. Birdsfoot trefoil constituted 37% of the yield in seeded plots and 36% in transplanted plots. In 1972, the legume increased to 82% from direct seeding and to 72% from transplanting. Thus, the extra work and cost involved in transplanting the legume was not needed, since a good stand of plant species could be developed from direct seeding.

Average 1971 yields from the more toxic Bolt Mountain spoil were about 3300 kg/ha for both birdsfoot trefoil and crownvetch seedings; however, legumes constituted only 18% of the vegetation during the seeding year. Average yield differences between phosphate rock and superphosphate treatments were small. The study showed that the birdsfoot trefoil population increased to 28% in both the direct seeded and transplanted plots, while the crownvetch population increased to 41 and 50%, respectively.

Using the terrace technique on the outer slope before applying amendments and seeding was successful in obtaining early seedling development and plant establishment. The added advantage of improvement of soil-water relationships in the grooves aided rapid germination of plant species.

Western Maryland

One experiment at the George's Creek site was primarily a test of plant species establishment on

TABLE 1. Average yields of dry matter from outer slope studies in West Virginia during 1971 and 1972

Phosphorus Treatment	Method of Establishment	Dry Matter Yield, lb/ac: Wheeling Site		Bell Mountain			
		Weeping Lovegrass and Birdsfoot trefoil		Weeping Lovegrass and Birdsfoot trefoil		Crownvetch	
		1971	1972	1971	1972	1971	1972
4.6 MT/ha Rock	Seeded	3990	6000	4334	[illegible]	3061	[illegible]
	Transplanted	4738	8760	2991	[illegible]	4978	[illegible]
6.8 MT/ha Rock	Seeded	6245	7852	*	*	*	*
	Transplanted	2542	[illegible]	[illegible]		[illegible]	
9.2 MT/ha Rock	Seeded	3891	[illegible]	3887	5234	4052	[illegible]
	Transplanted	4970	6026	3264	5116	2234	[illegible]
13.7 MT/ha Rock	Seeded	*	*	3588	4776	2701	[illegible]
	Transplanted	[illegible]		2452	4413	2947	[illegible]
352 kg/ha P_2O_5 (Super)	Seeded	5403	[illegible]	3962	[illegible]	3500	[illegible]
	Transplanted	5438	[illegible]	3691	5615	4389	*

*These rates not included at the respective locations.

Figure 4. A steep outer slope before establishment of vegetation

Figure 5 Tufcote Bermudagrass makes excellent cover for an outer slope with a southern exposure

a steep outer slope with a southern exposure. Fig. 4 shows the original configuration of the outer slope before construction of lateral grooves, amendment, and seeding. Tufcote Bermudagrass, established by hand transplanting sprigs, grew well and afforded almost 100% coverage by the end of the first growing season (Fig. 5). In the Ky-31 tall fescue-switchgrass seeding mixture, the tall fescue germinated well and grew well in 1973 in spite of drought conditions during the summer. The switchgrass germinated slowly and grew poorly during 1973. However, the establishment and growth increased, both in 1974 and 1975. The seeding to flat pea-red fescue was not successful, because flat pea failed to germinate and the red fescue germinated poorly. In 1974 and 1975, the stand of red fescue enlarged but still did not provide adequate cover. The germination and establishment of birdsfoot trefoil-crownvetch seeding mixture was very good for both plant species in 1973. Crownvetch continued to grow well during 1974 and 1975; however, birdsfoot trefoil became infected with anthracnose. High temperatures in the spoil surface on the south slope may have favored the disease. Progress of this experiment was documented by observations, since it was not feasible to disturb the slope coverage by harvesting the vegetation.

At the Frostburg site on the day of seeding and mulching, 6.25 cm of rainfall fell in a 2-hr period. The lateral grooves effectively contained the torrential rainfall with only a few breakthroughs by surface water runoff. One week later good germination was noted on all direct seeded plots. The hand-transplanted bermudagrass sprigs, planted five weeks previously, were growing well after withstanding drought conditions from time of sprigging until the rainfall.

During the seeding year (1974), tall fescue made excellent growth, while crownvetch was established slowly; however, in 1975 the crownvetch plants became well established and composed about 25% of the vegetative population. Also, tall fescue and birdsfoot trefoil grew very well throughout 1974 and 1975. Weeping lovegrass establishment was excellent and grew the best of all the plant species, continuing to provide coverage through 1975 and into 1976. Except for the Bermudagrass plots, the entire experimental area had excellent vegetative

cover that resulted in very good erosion control.

Tufcote Bermudagrass did not become well established at this location. The surface spoil around the plants eroded during heavy rains a few weeks after the sprigs were transplanted, leaving the propagating rhizomes too close to the spoil surface. During the winter of 1974–75, many of these exposed plants were lost to freezing on the northern exposure. Some recovery occurred during the spring of 1975. The kill during the following winter was attributed to lack of adequate snow cover to insulate the rhizomes. We observed, however, that although the Bermudagrass was dead, the plants still provided groundcover and the rhizomes still held the spoil in place.

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DISCUSSION

D. Hensley (Indiana, Purdue, USA). Did you monitor the pH after you applied the lime and what was the pH after initial application? What was it over a period of several years?

Griebel. I can't give you an exact answer on these specific sites, but in companion experiments the lime and rock phosphate treatments that we used will bring the pH up to around 4.5. There is a danger in using lime and rock phosphate. We're assuming there is enough acidity in the soil to convert the rock phosphate to a soluble form which can be used. If you raise the pH much beyond 4.5 you will decrease this. This is why you do not get an increase in yield when you go high on rock phosphate because there is only so much soluble and this is when you keep the pH about 4.5. We have done other studies and have determined that in a couple of years after turf is there, when you begin to build organic matter, the pH can go up to around 6. But we also find that the pH does not change beneath the place where we have put our amendments. In other words, the lime and rock phosphate are not moving down and, like I said, these experiments took place in 1971 and they still look just as pretty now as they did then.

Hensley. I was asking primarily due to the crownvetch. Some of the work on this indicated it did better as pH approached neutrality.

Griebel. I think in the case of any legume this would be true. However, crownvetch is one of our better plants and we've got it three feet tall down on Bolt Mountain; it was put there in 1970. So, again we can't answer. We know it's been there at least six years, and it's still doing very well.

H. F. Massey (Kentucky, USA). As you know, different sources of rock phosphate vary a great deal in their availability and I wonder if you had information on the source of the rock phosphate that you used?

Griebel. The source has been from the Texas Gulf Sulfur Company in Aurora, N.C.

R. Singh (West Virginia, USA). Did you make any measurements on yield after 1972 between the rock phosphate plots and those where you applied superphosphate? Was there any decline in the yield where you applied the superphosphate compared to the rock phosphate?

Griebel. We observed them every year. However, we have not taken yield measurements since 1972. There is a gradual decline and, like I say, where you have crownvetch it's going to crowd out everything else and take over. The birdsfoot trefoil does not seem to increase in dimension, but it stays there. It's not as pretty as it would be in more ideal conditions but at least it's there and it's doing its job. Again the problem we faced in 1970–71: Can we get something to grow? These were the questions that we were answering. Having answered them many times, we moved on to other things. So, we have not checked the yields, but the plants are still there.

Singh. Did you apply the superphosphate and the lime together?

Griebel. Yes, the superphosphate and the lime and the seed—it may all be done on the same day.

Singh. So, what you have done is convert the superphosphate to rock phosphate.

Griebel. Well, actually it works the other way around. You see, in the process of making superphosphate you take the rock phosphate and acidulate it, usually with sulfuric acid or something like that, and you'll make the superphosphate from the rock phosphate. We feel there's enough sulfuric acid in the spoil to do this job for us.

Singh. But, I'm talking about the superphosphate when you put it with the lime. You put the lime on the top of where you're putting a superphosphate. So the reaction solubility of superphosphate decreases.

Griebel. Yes, I understand.

J. Bennett (West Virginia, USA). Crownvetch is one of the most beautiful covers that we've found that will grow on a roadbank. It makes a cover for

prevention of erosion, but in your particular land use or productive use, what do you foresee coming in to replace the crownvetch?

Griebel. I don't know. It would take a very competitive grass or legume because the original (crownvetch) plots that we put in southern West Virginia about 1970, 1971, and 1972 now occupy an area 200 to 300% the size of the original planting. In other words, they're going to seed, being reseeded, and coming up from the crowns every year and nothing can grow in their shade.

Bennett. How about trees?

Griebel. By mistake, someone sprayed locust seeds on our plots in southern West Virginia and they took off very well. So, locust trees will do very well. But as to other species, I can't answer your question.

88.
Planning Criteria and Use of Highly Disturbed Soils*

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Surface mining of coal in the hill lands of West Virginia has been responsible for the creation of some new level lands. In places such as West Virginia, level land is a precious commodity; therefore, advanced planning of the mining operation based on reliable measurements of overburden properties is needed. After the mining operation is completed, the disturbed soils can be classified by properties (Sencindiver, 1977; Delp, 1975). Also, short- and long-range management of disturbed soils can be easily accomplished after mapping units are defined.

ADVANCE PLANNING

Planning a surface mine involves using available geologic maps and detailed exploration to estimate coal reserves. A three-step approach including overburden analysis is suggested for the study of overburden materials during investigation of the feasibility of development of a surface mine:

1. Geological and soil reconnaissance.
2. Regional study of physical and chemical properties of soil profiles and rock units of overburden materials as well as underlying coals.
3. Detailed analyses of appropriate samples to determine important physical and chemical characteristics of soil horizons and rock units of overburden at promising sites.

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Geological and soil reconnaissance consists of a review of information from private, state, and federal sources. Available information is generally confined to modern standard soil surveys, geological or soil association maps, physical and mineralogical descriptions of rock units, chemical analyses of coals, location of underground mines, surface mines, and coal prospects. Collection and analysis of selected dominant soil profiles and rock units of prospective overburden materials may offer early clues to future land use and reclamation opportunities.

Delineation of the physical and chemical relationships of overburden materials and associated coals is depicted by construction of generalized cross sections similar to those in northern West Virginia and western Maryland as illustrated in EPA reports 670/2-74-070 (Smith *et al.*, 1974) and 600/2-76-184 (Smith *et al.*, 1976). Sampling of correlative rock units can usually be obtained at exposures, abandoned and active surface mines, or from drill cuttings and cores along or adjacent to the line of cross section in areas of contour stripping. Cores and highwalls of active strip mines are usually the only sources of samples in environs of area stripping, often covered with unconsolidated deposits, e.g., loess, glacial till, and outwash.

The third-step in this system has become extremely important because the public in the United States, and possibly worldwide, has decided that extremely acid soils (pH less than 4.0) and biotoxic waters from earth disturbance activities are not acceptable. This is the reason for using an acid-base account, designed to assure against acid-induced toxic disturbed soils, as the overriding criterion to be consid-

ered before mining or other earth disturbance activities. A base-acid balance has been used successfully in East Germany to estimate the amount of alkaline fly ash needed for neutralization of acid-toxic spoil (Knabe, 1973). The German approach has been to determine total basic cations (calcium, magnesium, potassium, ammonium, and sodium) vs total strong acid anions (mostly sulfate but also chloride when present). Identical measurements could be applied in the eastern and midwestern United States, but it is simpler, cheaper, and equally satisfactory to determine total calcium carbonate equivalent vs immediately titratable acid plus potential maximum strong acid calculated from total or pyritic sulfur (the West Virginia approach). In either the German approach or the West Virginia approach, the idea is to assure a soil and water medium near neutrality and to prevent the pH from dropping below 4.0, which we have chosen to consider as a toxic level. The basis for toxicity, of course, varies, but aluminum and iron are so abundant in nature that these soluble elements occur at toxic or near toxic levels whenever the pH reaches 4.0 or lower, regardless of whether or not other soluble toxic elements are present.

CLASSIFYING DISTURBED SOILS

Following mining, the young mine soils are appropriate for classification based on properties. The mapping of such classes and recognition of practical mine soil phases is simplified by having good advance information about overburden materials and their placement during mining. Short-term treatments and long-range management follow conventional patterns as soon as mine soil mapping units have been defined, as is now being done in West Virginia (E. Wright, personal communication) and Ohio (N. Rubel, personal communication).

The present definitions of disturbed soils classes and mappable units reject the idea that such soils are too variable for separation into any kind of meaningful units. At the same time, the approach in West Virginia emphasizes that feasible mapping units often will include a degree of profile disorder and a range of certain properties in excess of acceptable limits for conventional soil series definitions. This is the reason for suggesting general soil classification and mapping at the family level of taxonomy, which does not in any way restrict further refinement into series wherever series criteria can be satisfied. Yet, emphasis on the family level, which is widely accepted as the highest pragmatic level in the scheme of modern scientific soil taxonomy, tends to prevent the frustrations felt by advocates of detailed homogeneity when faced with lateral and vertical changes in color, texture, and layering that violate common concepts of the soil series. Such variations are normal in many man-made soils because of placement practices. They do not ordinarily conflict with family definitions that have been worked out and tested throughout the Appalachian and midwestern United States. It is the profile details inherent to normal soil series definitions that would result in an unwieldy number and complexity of units if accepted as the basis for mapping.

SPECIAL PROPERTIES OF SPOLENTS

Studies in West Virginia (Smith *et al.*, 1974, 1976) favor placement of all highly disturbed minesoils in one soil order—Entisols. These are soils with little or no pedogenic horizonation, except a moderately differentiated horizon at or near the surface where weathering and initial biological activity are intense. Other apparent horizons, in the absence of a high water table, represent original manipulation and placement more than post-placement processes. Such layers lack the stratification typical of water-laid deposits. They include a wide range of particle sizes as well as pockets and lenses of contrasting materials, but they lack the erratics or foreign rocks found in glacial deposits.

Since none of the present suborders of Entisols are designed to accommodate man-made soils, a new suborder of Spolents has been defined. Spolents have the properties of Orthents, plus at least three additional properties, out of nine special properties, that convey more information about the nature of man-made soils. These properties and their direct or implied significance are:

Disordered Coarse Fragments

If coarse fragments constitute at least 10% of the volume of the control section (25 to 100 cm depth in the profile), they are disordered such that more than 50% will have their long axis at an angle of at least 10% relative to any plane in the profile. The test for disorder should exclude fragments with longest diameter less than 2 cm or greater than 25 cm and should be based on numbers of coarse fragments rather than volume. The disorder of coarse fragments provides assurance against extremely different perviousness in any direction in the profile.

Color Mottling Without Regard to Depth or Spacing in the Profile

The mottling involves color differences of at least two color chips in the standard Munsell soil color charts. This mottling occurs among fines as well as within coarse fragments or between fines and coarse fragments. Mottling, as described, indicates contact between chemically contrasting materials. This may either be desirable or undesirable depending on the chemical action involved. Mottling is most prominent in soils containing appreciable extremely acid material.

Splintery Edges on Fissile Coarse Fragments

If coarse fragments are fissile, the edges are frayed or splintery rather than smooth. Frayed or splintery edges of fissile coarse fragments often shelter voids coarser than textural porosity, and such edges are physically weak against any physical weathering process.

Bridging Voids

Coarse fragments bridging across voids as a result of placement of materials leave discontinuous, irregular pores larger than textural porosity. Such voids are present consistently but vary in frequency, prominence, and size. Bridging voids may seriously reduce unsaturated flow of water. They may result in more water being retained under low tension, and they may help prevent excess compaction. When large rocks are involved, they may cause or contribute to sinks or depressions in soil surfaces.

Thin Surface Horizon Higher in Fines

A thin, near-surface horizon, often immediately below a surface pavement of coarse fragments, contains a higher percentage of fines (less than 2 mm) than any other horizon in the profile to the bottom of the control section (25 to 100 cm depth in the profile). This horizon ranges from 2.5 to 10 cm thick in most minesoils, but it may be thicker in minesoils that have been "topsoiled" or manipulated intensively. These horizons with more fines usually contribute to better seedbeds and retention of moisture near the surface; however, they may be subject to serious erosion on steep slopes unless protected by coarse fragments, mulch, or good vegetative ground cover.

Local Pockets of Dissimilar Material

Local pockets of dissimilar materials, excluding single coarse fragments, may range from 7.6 to 100 cm in horizontal diameter. These pockets have no lateral continuity and are the result of the original placement of materials and not of post-depositional processes. They may differ from the surrounding material in color (two or more Munsell color chips), soil textural or particle-size class, dominant rock type constituting the coarse fragments, or in moisture retention. Pockets of contrasting materials can contribute needed nutrients or toxic elements.

Presence of Artifacts Within the Profile

This includes plastics, glass, paper, metal, tires, logs, etc. Artifacts provide confirmation of man-made origin, especially in cases where soils are similar to other Entisols. These foreign materials can contribute either nutrients or toxins and can alter water or air relations.

Carbolithic Coarse Fragments in Noncarbolithic Classes

These coarse fragments, which are usually associated with a coal horizon, are found in the profile because of moving and mixing of overburden materials. Whenever carbolithic fragments (rocks that have a color value of less than 3 when powdered) are present, they may be centers of pyritic weathering or release of nutrients or toxins associated with coal or carbon.

Irregular Distribution of Oxidizable Carbon with Depth in the Profile

This irregular distribution is due to the mixing of over-burden materials. Both recent and geologically old carbon compounds are involved. This property helps identify Spolents in questionable cases, especially when coarse fragments are sparse or absent. This property can mean that there will be more centers of nutrients deep in the soil profile and less concentration of organic-related properties near the surface.

It is not our intent to discuss details of suggested Spolent classes at the great group, subgroup, and family levels since this has been done elsewhere (Smith *et al.*, 1976; Sencindiver, 1977; Delp, 1975). It should be sufficient to indicate that two great groups of Spolents are suggested, based on moisture regimes. Under the humid great group, nine subgroups have been defined. They are based on rock types, except for the matric subgroup which has less than 10% coarse fragments (by volume) in the control section. This subgroup occurs where bedrock weathers very rapidly or where the overburden consists of unconsolidated and essentially stone-free, wind-blown, or water-laid sediments. It is a more common subgroup in parts of the midwestern United States and in parts of Europe. A need for lithic subgroups (less than 50 cm to bedrock) is anticipated, as well as subgroups with impeded drainage. Such subgroups have not been specified precisely because of their apparently limited significance, at least in the Appalachian and midwestern states of the United States.

Family criteria in *Soil Taxonomy* (USDA-SCS, 1975) include texture, dominant mineralogy, reaction at the top of the control section (four classes), and soil temperature regime (all mesic in West Virginia).

FAMILY PHASES AND MAPPING UNITS

Complex landscape patterns are not uncommon in detailed mapping of undisturbed soils or rocks. The degree to which homogeneity of units can be achieved in practice is highly variable and sometimes difficult to establish. It depends on the properties considered and the allowable range in each as much

as it depends on the blanket vs ribbon, pod, or channel nature of the rock or soil bodies. Since minesoils like young glacial till reflect mass placement rather than surface climatic, vegetation, and topographic patterns, it is inevitable that objects will come to rest together having unlike or contrasting physical and chemical properties. The degree of contrast will depend on the nature of the soil and rock materials being disturbed as well as methods used; however, the general characteristic of difference caused by placement is normal rather than exceptional. A certain detailed non-homogeneity, therefore, characterizes and defines all minesoils or Spolents. At the same time, it should be understood that this lack of detailed homogeneity does not in any way prevent Spolent bodies from falling within reasonable limits of important properties that can be recognized and mapped. These are the properties used at the family and higher levels of the soil taxonomic system.

Detailed properties reflecting non-homogeneity of placement would be considered more seriously in soil series definitions, which we are not using at this time. Rather, the classification scheme being advanced concentrates on practical properties below the family level only when these properties influence strongly or control local land treatment and management. If mappable, these low level but highly important properties should follow accepted terminology and be designated as phases of families or as variants outside the limits of the family definition. If not mappable at the scale being used and within limitations of time available for mapping, such properties should be handled by detailed descriptions of the usable mapping units.

In general, the need for the definitions of phases and variants will be decided locally but should be reviewed to assure against unnecessary conflict with broad perspectives of the National Cooperative Soil Survey or with *Soil Taxonomy* (USDA-SCS, 1975).

Examples of needed phases would be: steep slope; stony; mollic surface; loamy surface; and fly ash surface. Each of these phases might strongly influence land use by interaction with the local situation. Steep slope and stony might both occur together, constituting one steep slope and stony phase. A mollic, loamy, or fly ash surface phase might provide a useful indication of land suitable for plowing. Mollic, in addition, would imply the generally desirable surface physical and chemical properties of the mollic epipedon. Neutral, alkaline, or acid designations might be combined with other surface horizon phases when appropriate, especially where surface reaction contrasts with reaction of the control section.

Recently, some observations have suggested that rock type variations within the typic subgroup can be excessively broad. If it should appear feasible to map finer distinctions in rock types, this could be handled by designating phases. We would recommend retention of typic as a broad subgroup because it is well known that situations are common where proportions of different rock types vary widely within short distances. Mapping at the subgroup level, therefore, might be extremely difficult if finer distinctions were required. At the level of phases of families, on the other hand, it would be reasonable to make finer local separations to satisfy some practical objective: for example, a typic subgroup with sandstone phase to distinguish it from a limestone phase where the most abundant coarse fragment was limestone. Before making such phase distinctions, it should be recalled that texture, pH, and mineralogy at the family level might provide essentially the same demarcation, possibly making the proposed phases unnecessary. But if the phase could be mapped and if it conveyed additional useful information, such a designation would be appropriate with no confounding of classification at higher levels of abstraction.

Satisfactory mapping units on the newly formed landscape must indicate properties and suitability for particular management and use. Since the mapping units encompass major properties, they provide a basis for developing improved precision from research and experiences. New or improved information can be transferred onto similar minesoils by means of consistent mapping. The normal range of properties within family definitions indicates limitations to be expected when transferring data within a particular family or phase of family. Established mappable units represent a major step forward from the situation where all highly disturbed soils were lumped together under such terms as spoils or wastes.

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DISCUSSION

T. Bradshaw (Liverpool, England). I'm not sure whether you included amounts of pyrite in your classification. I would have thought that, from a biological point of view, such was more important than anything else in relation to soil development.

Sobek. We're including effects of pyrite, the reaction, the pH, as to what category the soil is going into. However, the public in the United States is no longer going to tolerate acid mine soils; therefore, the amount of pyrite is considered in the pre-planning phase. The rock type containing the most pyrite is eliminated from the soil profile. In other words, the overburden is considered before stripping begins and the problem is eliminated before the earth is moved because under West Virginia's control placement system the highly pyritic materials are either buried or blended with neutralizers, calcareous shales, or limestones to alleviate that problem.

Bradshaw. I meant in soil classification.

Sobek. At the family level—that could be a phase. It could be classified as a phase if there were highly pyritic materials left within the solum of the minesoil profile but we haven't run across any.

O. L. Bennett (West Virginia, USA). The answer right now is they do not.

F. Glover (West Virginia, USA). Could pyritic materials be included in a classification level of rock type?

Sobek. It could. However, in the past six or seven years we haven't found that it needed to be included in definition of rock type because we found out that pyritic materials aren't generally concentrated in just one particular rock type. Usually what we've found has been that as you approached the coal seam, going from surface downward through the overburden, sulfur content and pyritic sulfur content increases until it reaches a maximum at the coal seam. However, again I have to stress this, we found that in many instances regardless of the amount of pyritic material that's been in each particular rock type—each rock type has contained enough neutralizers or base to take care of the acidity that would be produced by the oxidation of those pyrites. In many instances the amount of bases overwhelms the amount of acidity that can be produced by the complete oxidation of the pyrites present.

W. Armiger (Maryland, USA). It seems to me that we've got a lot of the orphan mine spoils around that do contain pyritic material close enough to the surface to be of interest and even though there may be enough calcareous material in the profile to neutralize the pyrite as it acidifies, this still has an awful lot to do with the types of reactions that are going on in there—the salts that are going to be produced. A weathering material that has pyrite in it producing acids, even though there may be enough calcium-magnesium carbonate in there to neutralize them, is quite a different thing from one that doesn't have either the pyrite or the calcareous material in it.

Sobek. First of all, the classification system of soil taxonomy is based on the control section which is 10 to 40 inches. One of the reasons that it was put at that depth was the fact that this is the zone that is going to dictate long-term usage. Starting at a 10-inch depth from the surface, this area is not going to be as rapidly affected by weathering or manipulation of the surface. Most of the weathering effects of pyrite that could influence classification are going to take place at the contact of the atmosphere with unweathered minerals and this would be mapped out as a phase if it became that important.

89.
Reclamation of Mined Hill Land—Management Factor Interactions

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According to figures compiled by the USDA Soil Conservation Service, as of the beginning of 1974, over 763 000 ha of land have been disturbed by surface mining in eight Appalachian states. This region is dominated by mountains and hills of varying slope, extent, and elevation. It is humid, with yearly rainfall averages between 1 000 and 1 500 mm.

The greatest proportion of mining by far is for coal. Because of the rolling-to-steep terrain, nearly all surface mining is by contour strip mining. In this system, overburden is removed from the coal seam, starting at the outcrop and proceeding around the hillside. The cut in the earth appears as a contour line. After the exposed coal is removed, successive cuts are made back into the hillside until the overburden depth becomes too great for economic recovery. The overburden is either cast down the hillside, stacked along the outer edge of the bench, or moved laterally for placement in parts of the pit from which coal has already been removed.

Major variations of this mining technique in use throughout eastern mountainous regions of the U.S. include "mountain top removal," by which the overburden material is moved laterally and used to fill in nearby depressions; and the "valley fill" technique, where overburden material is deposited in the head of a cove, in effect shortening the associated valley. Since there is no profit involved in movement of the overburden material, it is common practice to move it and grade the material into final place only to the minimum extent necessary to enable compliance with statutes regulating reclamation of the mined land. These laws vary from state to state within the Appalachian region, but all states have requirements that provide for a minimizing of erosional loss of excavated overburden material, for complete vegetative cover of the mined land before state-held bond monies are released, and for variable specifications relating final site topography to the intended future land use and to pleasing aesthetic appearance. Details of the various surface mining methods are described by Grim and Hill (1974).

In addition to consistently hilly topography, both before and after surface mining, this region is underlain by a variety of geologic deposits ranging from sandstones through shales and mudstones, with various characteristics grading from relatively pure argillites to highly carbonaceous, and limestones varying from impure to metallurgical grade. The purity and occurrence of this complement of sedimentary rocks varies both laterally and vertically throughout the region. A few widespread and readily recognizable beds allow geologic correlation with a good degree of certainty. The three-dimensional variability of rock types and coincident properties are evident from exposure by surface mining operations.

The excavated materials form the foundation for man-made landscapes and comprise the parent materials of new soils which will develop on mined lands. Studies of the chemical and physical properties of overburden materials have led to the development of procedures for characterizing the various strata with respect to their degree of toxicity or favorability for placement after excavation to provide the best soil-forming medium, plant growth medium, and most stable landscape. Grube *et al.* (1973) and Smith *et al.* (1974) demonstrate the use of criteria for determining whether a section of coal overburden contains potentially toxic amounts of acid-producing minerals. These techniques are currently in use by many surface mining companies.

Investigations of the survival of plant species and varieties when established on mined land have been carried out by the USDA for many years. Although many studies were directed toward reclamation of acidic soils, primarily those with pH below 4 or 5, results of the numerous planting trials provided an insight into the adaptability of many plant species to soil conditions in which many agronomists would have predicted failure. These soil-plant studies have resulted in the publication of many intra-agency reports by experiment stations, USDA Soil Conservation Service, U.S. Forest Service, and other organizations providing recommendations for species selection and planting technique in disturbed soils in various localities. A recent survey by Donovan *et al.* (1976) documents the utilization of many different species for the vegetation of mined land and tailings and includes nearly 500 references.

A seedbed needs to be prepared in order to establish nearly every type of plant. This is usually carried

out by mechanical disturbance or smoothing of the soil surface to depths up to several decimeters. The exact nature of the seedbed required is determined by the plant cover desired. The final grading of a backfilled, mined area can usually be made to approximate a prepared seedbed, hence minimizing the amount of intensive labor required.

The type of planting equipment and techniques needs to be considered when selecting the final slope which will be acceptable. For example, if agricultural machinery is to be used, the final graded surface should be free of stone fragments larger than about 20 cm in the tillage depth. This stone-free requirement could be modified if the surface of the minesoil is composed of friable rock materials that easily break when tilled. It is important that the final surface grading does not excessively compact the soil to be seeded. If there is reasonable expectation that there will be surface traffic before planting, easily compacted earth materials should not be backfilled at the surface.

After elimination of obvious toxic materials, an evaluation of the overburden section should lead to selection of material from strata that have the most desirable physical and chemical properties for plants. Overburden movement and placement should be planned so these desirable materials ultimately become the backfilled and regraded minesoil surface. In regions where fertile gray or dark materials are selected, consideration needs to be given whether such material will create adverse microclimate for young plants if placed on sloping southern-facing parts of the mined area. On such sites, other light-colored earth materials, which may not be as favorable in other properties, may provide the best assurance of plant success. Alternatives to be considered include whether amendments, either light-colored mulches applied to dark soil surfaces or physical and chemical amendments to less desirable light-colored materials, may be a more efficient way to modify single disadvantages to placement of a specific material on certain parts of the regraded area.

Smooth seedbed preparation should be discouraged. There can be no justification for such meticulous workmanship either from an economic, aesthetic, or conservation viewpoint. Particularly on sloping areas, rainfall will easily remove the fine soil particles which are essential for all aspects of plant survival. The disadvantages of soil erosion are obvious and will not be discussed further here. Any aesthetic reasons for smooth surfaces can be discounted with the notation that, except in flood-irrigated fields, no agriculturally tilled land area is graded to extreme smoothness; even the vast grain fields of the plains states are developed with small ridges of up to 10 or 15 cm height. Ridges of this magnitude are reduced significantly after a few storms. Mining economy and soil conservation considerations demand the maximum allowable surface roughness of the backfilled area to suit the proposed future land use and immediate plant establishment techniques.

Many of the natural properties of minesoil surface materials can be altered to effect improved chances for reclamation success by the addition of physical and chemical soil amendments. Lime is commonly applied where soil tests show that the high acidity may cause low plant nutrient availability or high solubility of plant-toxic elements. Agricultural lime is, therefore, an amendment of widely recognized value and use. Fertilizers are added where soil test results, or in many cases tradition or empirical success show that additional plant nutrient elements need to be applied to support the desired plant cover on the reclaimed area. It is not yet widely recognized that some sedimentary rock strata overlying Appalachian coal seams are relatively richer in essential plant nutrient elements than neighboring strata. Evaluation of the nutrient element supply, both short-term and long-term availability, and selection of richer strata, maintaining consideration of other properties such as potential toxicities, rock fragment breakdown rate, ultimate particle sizes, etc., can provide minesoils in some areas that will have a relatively low fertilizer-maintenance requirement for many of the types of plants selected for revegetation. Again, plant species can be selected, within ranges, for tolerance to minimal maintenance fertilization if there is no other severe restriction dictating species choice.

A mulch has been defined as, "A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature" (Council, 1974). The materials used for mulching effect have varied widely. The value of these amendments in modifying the minesoil surface until the expected vegetation has reached a significant degree of thrift and ground cover is still not recognized by many mine operators and revegetation advisers. Favorable effects provided by simple expedients, such as hay mulch, can enhance reclamation of steep slopes, improve poorly prepared seedbeds, stabilize soil surface materials, modify soils receiving large amounts of solar radiation, and absorb the impact of severe rainfall so that young plants can develop to a point where they are capable of surviving in the new soil and landscape. Successful revegetation can frequently be enhanced by spot treatment with amendments. If an area generally possesses favorable characteristics except for isolated embankments, dark soils, aspect, or poorer surface physical properties, such spots should receive individual treatment, rather than following a uniform prescription over a certain contracted acreage. Spots with atypical properties

need to be recognized by revegetation planners even though regrading or topsoiling practices have been intended to result in uniformity over the entire area to be revegetated. Porous soil materials with potentially poor waterholding characteristics may be improved by both topsoiling and heavy mulch applications, followed by selection of species having extensive root systems to gather sparse soil water.

Bennett (1971) observed that crownvetch, birdsfoot trefoil, bluegrass, fescue, and Bermuda grass on 30–35% south-facing slopes started spring growth at least three weeks earlier than on 30–35% north-facing slopes at Morgantown, West Virginia (latitude 40° N, altitude 320 m). He also found that to depths of 60 cm in a Gilpin silt loam (Typic Hapludult) the average amount of available soil moisture throughout the growing season on the north-facing slope was about twice that found in the soil on the south-facing slope.

He observed temperature differences of more than 23° C between northern and southern exposures of bare soil. The soil surface on southern exposures exceeded 51° C several times during summer months and reached a high of 62° C. Mid-winter maximum soil surface temperatures were up to 17° C higher on southern exposures. Soil temperature maxima at depths of 2.5 and 7.6 cm were similar to soil surface temperatures. Lee (1975) and Deely (1970) have shown the high soil surface temperatures that may be reached on minesoil surfaces composed of various rock types. Their data show that high temperatures lethal to plant seedlings are readily attained by dark soil surfaces on mined lands.

Fig. 1 presents the importance of interactions between pairs of factors often considered singly in a mined land reclamation plan. This chart shows

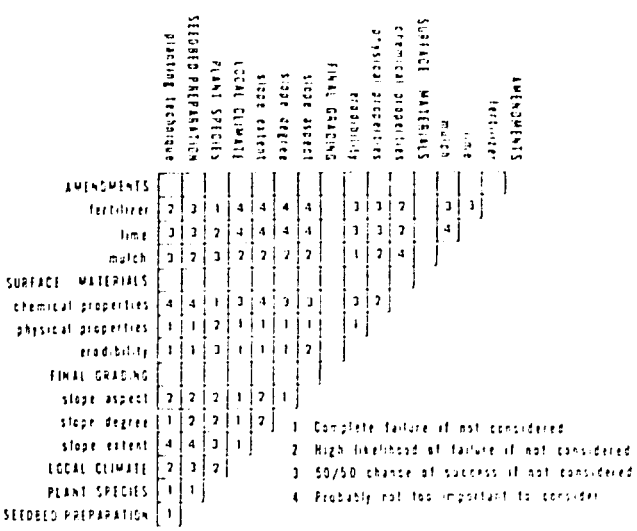

Figure 1. Significance of interactions among edaphic, climatic and biological parameters in assuring reclamation success.

that physical properties of the minesoil, erodibility of the soil, plant species, and slope are the most common factors that interact with others to result in low revegetation success.

Minesoil physical properties directly influence soil erodibility; the latter becomes more intense with increasing slope gradient and increasing length of slope. The heat-absorbing capability of a mined land surface depends on the thermal absorptive and conductive properties of the surficial materials and their placement with respect to solar radiation. This suggests that dark refuse materials be placed on north-facing slopes and lightest colored materials be reserved for south and west slopes, or consideration of topsoiling or heavy mulching of slopes that could be expected to become fatally hot on summer days. As slope inclination increases, coarse soil and rock fragments should be placed on the land surface to retard erosion. Fine-textured soils should be moved to the more level section of the site during final grading. Long slopes, over a few tens of meters, should contain rock fragments that will tie in soil materials to minimize downslope slippage; clayey overburden materials must not be used in the basal part of a constructed long slope. If the regional climate includes short, high-intensity precipitation of generally seasonal nature, the backfilling and regrading operations should be planned to produce the least erodible surfaces between the time of year of final grading and the time when vegetation completely covers the soil. This implies that a standard grading technique should not be used; final grading should promote the type of land surface that is needed for immediate erosion minimization and ultimate land utilization.

Drought tolerant plant species need to be selected for coarse textured minesoils that may develop severe moisture stress. Surfaces that appear to be composed entirely of rock fragments usually contain sufficient soil-sized particles between coarse fragments to allow plant growth; even on very steep slopes, seeds and seedling can become established if sufficient rock mulch is present to prevent massive erosion. Where coarse fragments are prevalent on the final minesoil surface, seedbed preparation may be minimal. In these cases, advantage should be taken of naturally eroded soil on leeward sides of fragments for seed cover; coarse mulch materials can provide seed protection until the emerging plant can fend for itself. Where broadcast or hydroseeding is practiced, overspreading mulch or surface roughening with rugged equipment is necessary unless plant species which establish from surface seed placement are being used.

Erodibility may be more important on windward sides of major topographic features. Local slope aspect should be considered if advantage can be gained from long-term accumulation of eroded soil

on the leeward side of microtopographic highs. Materials that readily fragment into silt and finer sizes should be reserved for shallow slopes, with larger fragments and more resistant types placed on the steepest slopes. Early planning of regrading should disallow long slopes of any nature; diversion ditches and other breaks in slope must be constructed of resistant materials. Microtopographic regions of a mined site that can be expected to carry water during locally intense storms, where these are common or expected, should be composed of the most resistant materials available. Plant species which develop extensive and deep root systems should be selected for highly erodible areas until the site has been stabilized and the long-term planned use can be fully implemented.

Minesoil surfaces that contain readily eroded materials should receive minimum disturbance during seedbed preparation and planting, consistent with the demands of the seed species to be used. The formation of a crusted surface promotes runoff of rainfall, while gully development concentrates the forces at work in removing the soil. Where rock fragments are few, use of cultipackers, rollers, or similar treatment of the planted area may be beneficial.

The survival of different plant species under the wide variety of environmental conditions extant on minesoils has probably been studied more than any other single factor. The many such references cited by Donovan *et al.* (1976) attest to this. Substantial amounts of personal preference have entered into major criteria of species selection. Little consideration appears to have been given thus far to plant successional systems that research and experience have shown are at work in newly planted environments. The nutritional requirements and micro-environmental factors most favorable to a given species are often well known. The largest errors that remain in species selection are probably on sites where the landowner opts for the passive conversion to "woodland," or "wildlife," and similar non-intensive uses. On such lands, plants most suitable from the aspects of soil and site properties can even enhance the soil and water conserving and wildlife supporting properties of the site.

Slope is an inherent property of mined hill lands. It can be modified and manipulated to better advantage than natural erosional forces have provided, and external practices can be applied to improve soil conservation, plant establishment, and pollution minimization in hilly country that is mined. The massive earth movement involved in surface mining allows manipulation of the final land surface to achieve nearly any configuration desired for economic land use. However, some legal restrictions exist that place limitations on the types of final minesoil slope that are acceptable.

The natural meteorological interactions with land slope are primarily related to the direct effect of rainfall and the indirect effect of microclimate due to variation in slope gradient and slope aspect. The latter factor has been well documented (Bennett, 1971, and Lee *et al*, 1975); soil temperature is lower and soil moisture is higher on slopes receiving less direct sunlight. Slope angles and aspects receiving the most sunlight have been shown to be potentially droughty and may attain plant-lethal soil surface temperatures. These extremes are only reached when the combination of meteorologic, topographic, and biologic factors are additive.

Mulching materials have been long used to "tack" seeds and fertilizers to sloping land. Further, their value in reducing erosion (especially hay or straw mulch) of bare soil is well recognized. These appear to be the only two primary values assigned to mulches. Application of mulch materials to modify the soil surface with respect to heat transfer properties or seedbed improvement where the mineral soil may be unfavorable has not been practiced to any great extent. On hill land, a heavy application of hay mulch can aid plant establishment from several aspects: surface-moisture retention in dry seasons, modification of heat absorbing soil and rock surfaces, mechanical protection and stabilization against erosion, entrapment of wind and water eroded particles from other areas, seed source from late-harvested hay, and reduction of evaporation of soil moisture.

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DISCUSSION

A. Sobek (West Virginia, USA). How do you get the information to federal legislators? I have been

working in reclamation for several years and we seem to be able to get it to mine operators, and we seem to be able to get it to the legislature on the state level, but materials that I see coming out of Washington don't seem to have any relevance to what is going on and what has been done in research.

Grube. There are several avenues open to us. The first one that comes to mind is that we are all citizens. Information generated by public funds—public research—is available to anyone. For those of you who don't already know, in this country the Freedom of Information Act provides you with access to any information obtained with public monies. I think the approach of a personal letter from you as an individual to your legislator, at any and all levels of government, is the most practical. Invite the higher level legislators on some of the field trips you make, and show them the results. The assistance of your higher level college administrators can emphasize the value of this research. Encourage and ask your professional societies to point out research accomplishments, adding their support and credence.

90.
Response of Four Grass Species to Rock Phosphate on an Acid Strip Mine Spoil

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Strip mine spoils should be revegetated as soon as possible to alleviate erosion and pollution of surrounding areas. Grasses and legumes should be considered for initial revegetation, even though trees may be the desired climax vegetation. The grasses and legumes furnish immediate cover and provide organic material to the spoil (USDA, 1968; Vogel and Berg, 1968).

Many strip mine spoils are acidic because of the oxidation of sulfides, which produces sulfuric acid. The resultant pH of the spoil material often results in toxic levels of aluminum (Al), manganese (Mn), iron (Fe) (Lowry, 1961), nickel (Ni), zinc (Zn), and copper (Cu) (Massey and Barnhisel, 1971).

The low pH spoils are often infertile, lacking especially in calcium (Ca), magnesium (Mg) (Struthers, 1964), and phosphorus (P) (Berg and May, 1969).

Preliminary studies using rock phosphate on acid spoil material (unpublished data) indicated that rock phosphate was effective in increasing yields of some plant species. Other authors have shown that rock phosphate can be an economical P source on acid soils (Alston and Chin, 1974; McLean, Brown, and Hawkins, 1952).

Plants differ markedly in their tolerance to acidic soil conditions, depending on their abilities to acquire nutrients or to tolerate high concentrations of mineral elements. For example, Foy *et al.* (1973) showed that Atlas 66 wheat is tolerant to Al but is sensitive to Mn, while Monon wheat is sensitive to Al but tolerant to Mn; weeping lovegrass is more tolerant than tall fescue to Al (Fleming *et al.*, 1974). Vogel and Berg (1968) reported that weeping lovegrass tolerates acid strip mine spoils of Kentucky while tall fescue does not.

The objective of this study was to evaluate the tolerance of four plant species to acidic strip mine spoil amended with rock phosphate.

MATERIALS AND METHODS

Mine spoil material from a strip mine area near Beckley, West Virginia (Table 1), was passed through a 6 mm screen and 1 200 g of soil was placed in paper cartons. The spoil was fertilized with 75 mg/kg N and 75 mg/kg K as NH_4NO_3 and KCl, respectively. Rock phosphate from North Carolina (Table 2) was mixed with the spoil at rates of 0, 100, 200 400, 600, 1 200 and 2 400 mg/kg. Weeping lovegrass (*Eragrostis curvula*), deertongue (*Panicum clandestinum*), little bluestem (*Andropogon scoparius*), and tall fescue (*Festuca arundinacea*, var. Ky 31) were grown for 63 days; tops and roots were harvested, dried at 70° C, and weighed.

The top 6 cm of plants were ground in a Wiley mill to pass a 40-mesh stainless steel screen and dry ashed at 500° C overnight for analysis.

Mn, Zn, Cu, and Ca were determined by atomic absorption, P by vanadomolybdophosphoric-yellow method (Jackson, 1968), Fe by the colormetric o-phenanthrolene method (Saywell and Cunningham, 1937), and Al by aluminon (Chenery, 1948). Final

TABLE 1. Chemical characteristics of Beckley, West Virginia, strip mine spoil

Location	Spoil pH; 1:1 Soil:Water	Exchangeable Cations (meq/100g[a]) Ca	Na	K	Al	%[c] Al Saturation	Avail. P Bray #1	Exch.[b] Mn++ (mg/kg)	Exch.[b] Fe++ (mg/kg)
Beckley	4.2	1.22	2.3	0.21	2.39	32.1	14.3	41.2	25.1

[a]Ca, Mg, K and Al extracted from air-dried spoils with NH_4OAc at pH 4.0.
[b]Mn and Fe extracted from slightly moist spoil with NH_4OAc at pH 4.0.
[c]$\frac{Al}{Al+Ca+Na+K}$.

TABLE 2. Chemical analysis of North Carolina raw rock phosphate

Dilute Acid Sol. P = 82%
Total P_2O_5—30.0-31.0%
CaO—48.9-49.3%
MgO—0.5-0.6%
K_2O—0.1%
B—80 mg/kg
Zn—160 mg/kg
Mo—35 mg/kg
Cu—10 mg/kg

pH of the spoil material was determined in a 1:1 soil-water slurry.

RESULTS

Weeping lovegrass and deertongue were much more tolerant to the acid, untreated mine spoil and required much less rock phosphate for good growth than did little bluestem and tall fescue (Table 3). For example, the top yields of weeping lovegrass and deertongue were significantly increased over the no P treatment by rock phosphate rates up to 400 mg/kg but not by higher rates. Those of little bluestem and tall fescue were also significantly increased by rates of 400 mg/kg rock phosphate and, in addition, showed yield responses to the higher rates. Root yields of weeping lovegrass were not significantly different at rock phosphate rates of 0 to 2400 mg/kg. Deertongue root yields were significantly increased by 200 mg/kg rock phosphate but not by higher rates. For statistical maximum root yields of the less-tolerant little bluestem and tall fescue, 400 and 1200 mg/kg rock phosphate, respectively, were required. These marked differences in response to rock phosphate are clearly shown in Figures 1 and 2. The rock phosphate treatments which produced the maximum yield responses increased the spoil pH by less than 0.2

TABLE 3. Effects of rock phosphate on the top and root yields of four plant species grown in pots of an acid mine spoil (initial pH 3.96)

Rock Phosphate Levels mg/kg	Final Soil pH	Top Yield: Weeping Lovegrass	Deertongue	Little Bluestem	Tall Fescue
			g (dry wt)/pot		
0	3.9	0.77d	2.86c	0.13c	0.31d
100	3.9	2.46c	3.25c	0.28c	0.43d
200	4.0	4.47b	4.00b	0.38c	0.46d
400	4.1	5.13a	5.13a	1.23b	0.92c
600	4.1	5.03ab	5.21a	1.35b	1.43b
1200	4.1	5.37a	5.75a	2.47ab	1.81ab
2400	4.3	5.50a	5.28a	2.47a	2.00a
		Root Yield			
			g (dry wt)/pot		
0		0.88a	1.40b	0.15b	0.20c
200		1.16a	2.37a	0.25b	0.45bc
400		1.05a	2.94a	0.71a	0.56b
1200		0.92a	2.91a	1.05a	0.91a

[a]Within a species column, top or root yields followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

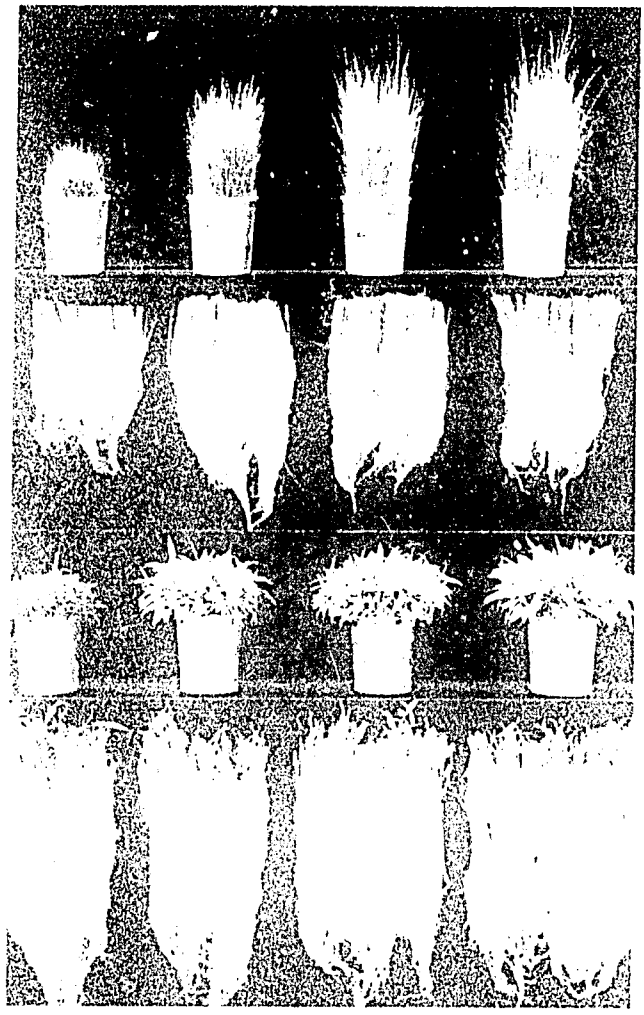

Figure 1. Response of weeping lovegrass [illegible] bottom to rock phosphate [illegible] right 0, 200, 400 and 1200 mg [illegible] rock phosphate. Final pH values were [illegible] 4.2, 4.1 and 4.2 respectively.

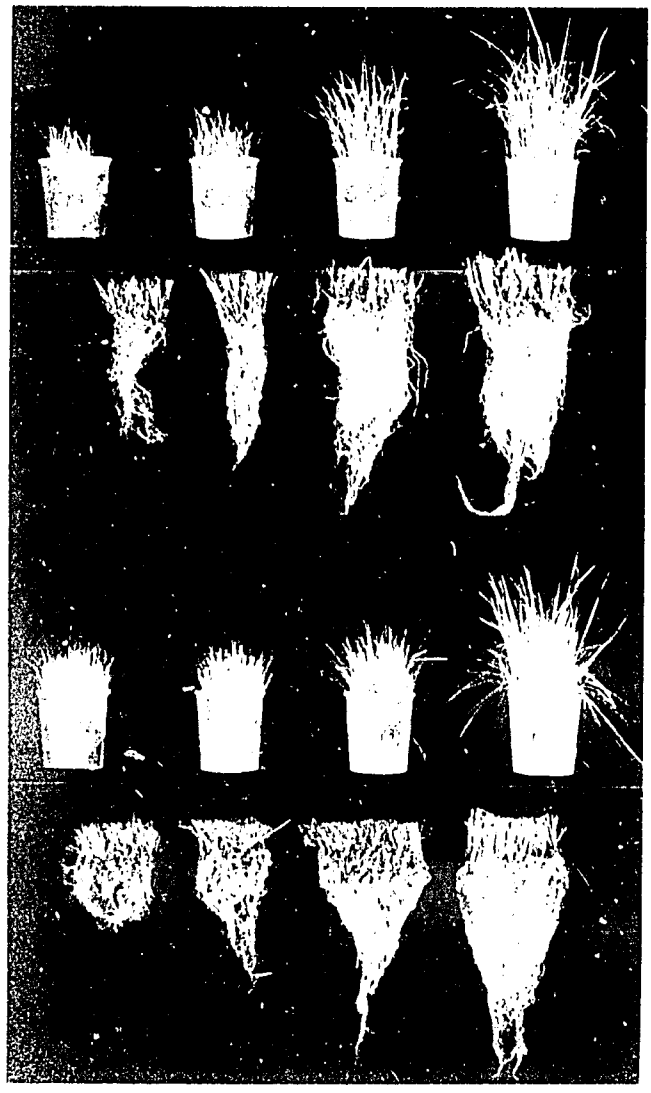

Figure 2. Responses of little bluestem (top) and tall fescue [illegible] to rock phosphate on an acid mine spoil (left to right [illegible] 0, [illegible] and [illegible] mg/kg rock phosphate. Final pH values were [illegible] 4.2, 4.1 and 4.1 respectively.

ants. Table 4 shows the mineral composition of the plant tops, although we analyzed all treatments. Several were not included in the table. Rock phosphate levels which produced the statistical maximum top growth (400 mg/kg for weeping lovegrass and deertongue and 1200 mg/kg for little bluestem and tall fescue) markedly increased P concentration in the tops, as compared with the control. The percent increases were 85, 102, 81, and 105 for weeping lovegrass, deertongue, little bluestem, and tall fescue, respectively.

Tall fescue is especially noteworthy because it accumulated higher concentrations of Ca, Al, Zn, and Mn than the other three species at the 0 and 100 mg/kg rock phosphate treatment (Table 4).

DISCUSSION

Weeping lovegrass and deertongue were more tolerant than little bluestem or tall fescue to the acid strip mine spoil.

This tolerance may be partially explained by their lower nutrient requirement or better utilization of available P, their ability to tolerate low pH levels, or their ability to tolerate high Al and Mn. None of the plant species tested had high Al contents in their top tissue; however, the roots of the nontolerant species showed characteristic Al toxicity symptoms, while those of the tolerant species seemed normal. This agrees with the finding (Fleming *et*

TABLE 4. Analysis of top tissue of four plant species grown in pots of acid strip mine spoil

Plant Species	Rock Phosphate	Ca	P	Al	Mn	Zn	Cu	Fe
		Percent				*mg/kg*		
Weeping lovegrass	0	0.311	0.041	34.4	927	275.0	8.60	53.8
	200	0.200	0.065	22.5	314	139.0	11.20	63.9
	400	0.206	0.076	32.5	325	93.3	10.80	27.1
	1 200	0.238	0.084	41.5	405	130.0	12.40	24.6
Deertongue	0	0.167	0.046	66.8	478	98.0	18.40	51.2
	200	0.149	0.074	43.5	543	95.6	4.35	58.7
	400	0.176	0.093	65.9	626	105.0	4.40	34.3
	1 200	0.229	0.123	88.2	719	102.0	4.64	183.0
Little bluestem	0	0.285	0.054	63.2	435	53.9		
	200	0.208	0.050	10.5	284	42.2	4.22	46.1
	400	0.176	0.073	19.4	214	35.0	9.73	37.7
	1 200	0.196	0.098	38.5	260	44.3	9.63	150.0
Tall fescue	0	1.410	0.062	85.7	2 346	387.0	15.80	1 828.0
	200	0.868	0.060	90.7	1 272	268.0	14.80	56.0
	400	0.535	0.083	98.8	1 121	245.0	15.40	27.1
	1 200	0.328	0.127	67.8	815	146.0	10.60	31.8

al., 1974) that weeping lovegrass was more tolerant than tall fescue to Al in nutrient solution.

All four plant species had relatively high Mn in their tops at low rock phosphate levels. Tall fescue accumulated much higher concentrations of Ca, Mn, Zn, and Cu than the other species tested. However, little bluestem did not accumulate high concentrations of any of the elements tested. Evidently, the physiological mechanism of acid soil sensitivity differs between these two species. Increasing rock phosphate levels increased P concentrations in the tops of all four species.

Rock phosphate seems to be an effective source of P for plants on acid strip mine spoils if acid-tolerant species such as weeping lovegrass and deertongue are grown. The low pH would tend to increase the availability of P from the rock phosphate. Even at the highest rate of rock phosphate applied, the highest pH was only 4.25. Other experiments (unpublished data) have shown that addition of limestone to spoil treated with rock phosphate inhibited plant growth. Apparently, as the spoil pH increased, P from the rock phosphate became less available.

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DISCUSSION

Tony Bradshaw (Liverpool, England). The thing I find most interesting about those results, which I think are fascinating, is that most of the phosphate internal concentrations seem to be so similar between

the four species. I was expecting to find that the weeping lovegrass, for instance, was going to have a much higher internal concentration than the arundicea. Would you comment on that?

Schwartz. I have no explanation. I'm amazed too. It seemed as though in all four species the phosphorus content from 0 to 1 200 treatment approximately doubled. You could have plotted it, and it would have made a beautiful graph. I have no explanation as to why they didn't differ more than they did. Evidently, the feeding power of these four species for rock is similar.

Bradshaw. Well, in some ways it is but in some ways the total uptake is critically different.

Schwartz. Because of yields?

Bradshaw. Right.

Schwartz. Also, you can't discount antagonism from other heavy metals, such as, zinc and manganese, and remember fescue had very high manganese—2 000 ppm vs 400 and 500 for deertongue and lovegrass. This is going to affect internal phosphorus, too; it can get very complicated.

91.
Tailoring Plants for Greater Tolerance to Mineral Toxicities and Deficiencies on Hill Land Soils

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Many soils on hill land topography are seriously eroded, strongly acid, and deficient in available essential nutrients for plant growth. Steep lands have generally been neglected in research, and soils of mountainous regions of the world are becoming seriously deteriorated through mismanagement (Eckholm, 1975). Soil acidity is frequently the first problem encountered in attempts to improve the productivity of hill land soils. In strongly acid soils and mine spoils (below a pH range of 5.5 to 5.0) toxicities of Al, Mn, and other mineral elements, or deficiencies of essential elements such as N, P, K, Ca, Mg, and Mo, may limit or prevent the establishment and growth of the desired crop (Kamprath and Foy, 1971). Phosphorus fixation (unavailability) is particularly serious in such soils. In legume-grass mixtures, N may be a limiting factor because of inhibited rhizobial activity.

Some hill land soils used for pasture are too steep for the use of conventional lime- and fertilizer-spreading equipment, and aerial application may be economically prohibitive. Furthermore, even when the surface soil (plow layer) can be limed, the subsurface soil remains strongly acid, preventing root penetration and decreasing drought tolerance and the use of subsoil nutrients. Heavy liming of surface soils does not correct subsoil acidity and may induce short- or long-term problems of micronutrient unavailability and encourage the development of certain plant diseases, especially in the tropics (Martini *et al.*, 1976). Thus, some problems of mineral stress in soils cannot be economically corrected with present technology. But certain plant species and varieties are known to differ widely in tolerance to high or low levels of mineral elements, and some such differences are genetically controlled. Hence, a promising alternative or supplementary approach to problems of mineral stress is to select or breed plants that are more specifically adapted to soil conditions that are not economically correctable.

Soil situations in which a plant-breeding approach looks promising include steep pasture land that is strongly acid and difficult to lime even in the surface soil layer; acid, Al-toxic subsoils (subplow layers) (Doss and Lund, 1975); strongly acid mine spoils on which rapid vegetative cover and soil stabilization are desired at minimum cost (Jones *et al.*, 1975); soils that are deliberately maintained at low pH levels (5.2 or below) to control the potato scab disease in potato-barley and potato-sugarbeet rotations (Hutchinson *et al.*, 1971; Kesar *et al.*, 1975); vast areas of strongly acid, Al-toxic, phosphate-fixing surface and subsoils of the tropics (Spain *et al.*, 1975; Salinas and Sanchez, 1976; Olmos and Camargo, 1976; Silva, 1976); saline soils (Rush and Epstein, 1976); soils polluted with heavy metals (Bradshaw, 1970 and Paper No. 76 in this Volume; Brown and Jones, 1975; Lagerwerff, 1974; Chaney and Giordano, 1976); and calcareous soils with Fe-deficiency or

other micro-nutrient problems (Brown *et al.*, 1972). A similar approach would be appropriate for soils that are either too wet or too dry. Even in "good" soils, fertilizer-efficient plant genotypes are needed to decrease crop-production costs, conserve fossil energy and limited fertilizer resources, and prevent groundwater pollution.

In the past, our soil fertility research and extension programs have emphasized changing the soil to fit the plant. As a result, many crop varieties have been developed under nearly optimum conditions of fertility and pH—that is, in the absence of any obvious mineral stress. When such varieties are introduced to soil regions that differ from those in which they were developed, they may show mineral stresses of various kinds. For example, the Green Revolution wheat variety, Sonora 63 (developed in Mexico), will not tolerate the strongly acid, Al-toxic soils of Brazil (Silva, 1976; and personal observation). By contrast, certain Brazilian bred varieties are quite tolerant to these conditions and may show little or no lime response at soil pH values as low as 4.7 (Martini *et al.*, 1976). In some cases, liming soils to pH 6.3 actually decreased yields by increasing the severity of the "take all" disease of wheat. In the United States, the Gaines wheat variety, which has set a world yield record of 11 343 kg/ha on 10.5 ha of irrigated land in the state of Washington (Bertramson, 1964), is extremely sensitive to Al in acid soils (Foy, 1974a).

The practice of fertilizing and liming the soil to "optimum" levels has been profitable in the developed countries, where supplies of energy, lime, and fuel were inexpensive and abundant. However, in many other parts of the world this approach has never been practical. Greenland (1975) has pointed out that the food production technology of developed nations cannot simply be transferred to the non-mechanized small farm situations found in many developing countries. Sanchez and Buol (1975) noted that "a strategy based on minimum inputs is gradually taking form within the tropical agronomy research community." Even in the developed countries, there is increased awareness that certain fertilizer resources are not inexhaustible. For example, recent Bureau of Mines statistics indicated that at the present mining rate, U.S. high grade phosphate deposits (three-fourths of which are in Florida) will be depleted by the year 2000 (Love, 1976).

A plant-breeding approach to soil fertility problems has several advantages. It is ecologically "clean," energy-conserving, and less expensive than changing the soil to fit the plant. The economy of the method is particularly important to these developing countries, which have little or no foreign exchange. The "good" soils of the world cannot support present and predicted populations. Even if this were possible, the worldwide distribution of food is impractical, if not impossible. The only reasonable plan is to produce crop and livestock products as nearly as possible to where they are needed. This often means using marginal or submarginal land and being satisfied, at least temporarily, with much lower yields than would be profitable in a mechanized agriculture, based on high inputs of fossil energy (Heichel, 1976).

DIFFERENTIAL TOLERANCES OF PLANTS TO MINERAL STRESS

In strongly acid soils (below pH of 5.5 to 5.0), Al- and Mn-toxicities are probably the most important growth-limiting factors. Manganese toxicity produces more clearly identifiable symptoms than does Al (Fig. 1), but Al causes much more drastic decreases in growth. Hence, when both problems occur on the same soil, the decreased growth may be attributed entirely to Mn-toxicity when Al-toxicity is the more important cause. In poorly drained or compacted soils, reducing conditions cause the production of divalent Mn which is absorbed by plants. Under such conditions, Mn toxicity can occur at soil pH values of 6.0 or above (Siman *et al.*, 1974), a level at which Al is not soluble in toxic concentrations. Manganese toxicity is also intensified by high temperatures and drought. Additional details concerning the effects of Al, P, Ca, and Mn relationships in plant growth are available in recent review papers (Foy, 1973, 1974a, 1974b).

Differential Al Tolerance

Plant species differ strikingly in their tolerance to Al. For example, weeping lovegrass (*Eragrostis curvula* [Schrad] Nees) is much more tolerant to acid, Al-toxic Tatum soil than is Ky 31 fescue (*Festuca arundinacea* Schreb) (Fig. 2). The acid-soil tolerance of these two species coincides with their tolerance to Al in nutrient solutions (Fleming *et al.*, 1974) (Fig. 3) and with their abilities to grow on acid mine spoils at pH 4.0 (Vogel and Berg, 1968). Both species are quite tolerant to excess Mn (Fleming *et al.*, 1974). Differential Al tolerance has been found among genotypes of barley (Foy, 1974a; Reid, 1975, Slootmaker, 1974); wheat (Foy *et al.*, 1974a); triticale (Mugwira *et al.*, 1976); rice (Spain *et al.*, 1975); Howeler and Cadavid, 1976); corn (Clark and Brown, 1974); soybeans, snapbeans, cotton, Irish potato, ryegrass (Foy, 1974a); alfalfa (Dessureaux, 1969; Buss *et al.*, 1975; Devine *et al.*, 1976; Simpson *et al.*, 1976); sugarbeets (Hutchinson *et al.*, 1971); sunflower (Foy *et al.*, 1974b); tomatoes (Foy *et al.*, 1973b); weeping lovegrass (Foy *et al.*, 1974c); green algae (Foy and Gerloff, 1972); and among species of soil-borne pathogens (Orellana *et al.*, 1975). Wheat genotypes differing widely in tolerance to an acid, Al-toxic Bladen soil are shown in Figs. 4 and 5. Differential

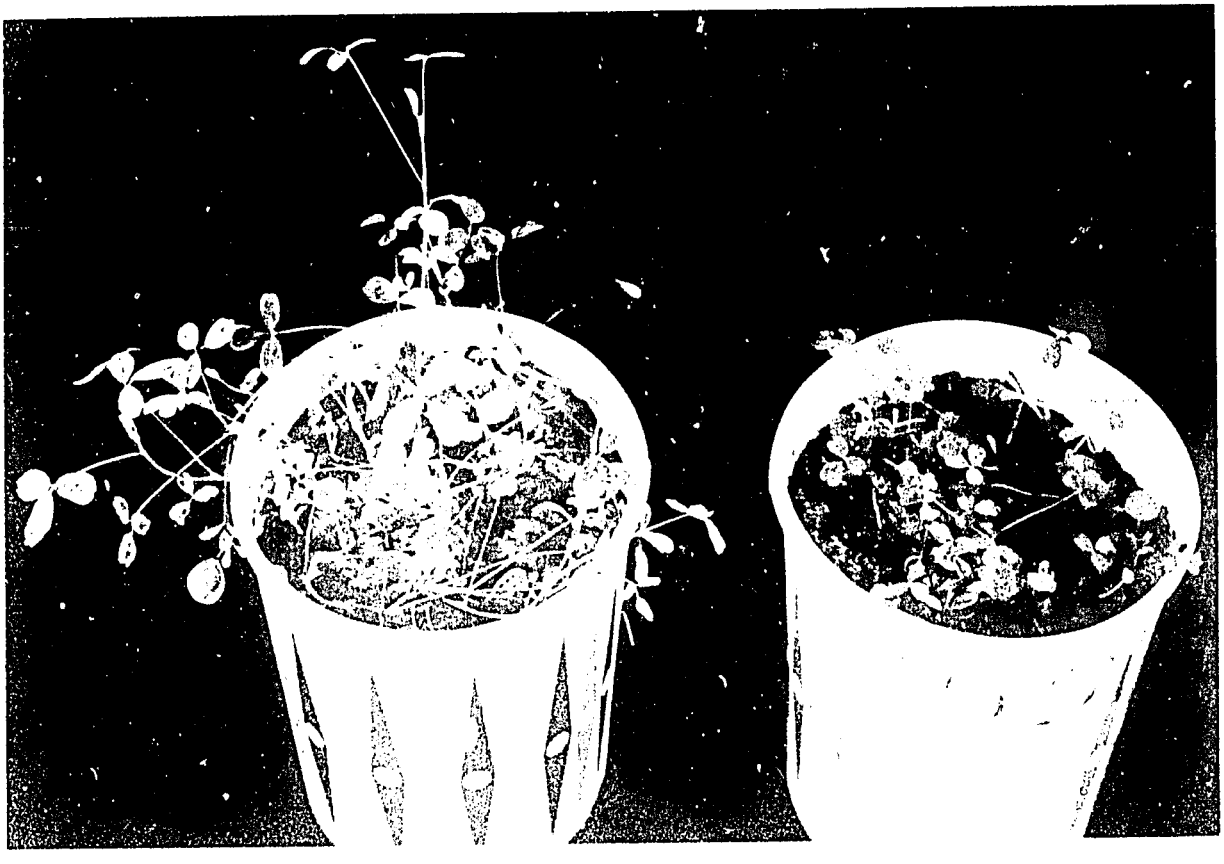

Figure 1. Contrast between Mn toxicity (left) and Al toxicity symptoms (right) in alfalfa. The soils are Ruston (pH 4.7) (left) and Bladen (pH 4.5) (right).

Al tolerance between the Thorne and Redcoat wheat varieties has also been demonstrated in nutrient solutions (Foy *et al.*, 1974a).

Differential Mn Tolerance

Plant species and varieties also differ in tolerance to excess Mn (Foy, 1973). For example, corn and rice are more tolerant than lespedeza, soybeans, or barley. Differential Mn tolerance has been reported for cultivars of soybeans (Carter *et al.*, 1975), wheat (Foy *et al.*, 1973a), cotton and clover (Foy, 1973) and for alfalfa clones (Devineau, 1959). Some plant varieties are either sensitive or tolerant to both Al and Mn, while others show opposite tolerances to excesses of these two elements (Foy *et al.*, 1973a). For example, Atlas 66 wheat from North Carolina is more tolerant to Al than Monon wheat from Indiana, but Monon is more tolerant to excess Mn than is Atlas 66.

Differential Tolerance to Alkaline Soils

In alkaline soils, the most obvious mineral stress problems are unavailability of micronutrients (particularly Fe), B toxicity, and salinity (Brown *et al.*, 1972). The Fe deficiency chlorosis syndrome on calcareous soils is an economically serious and physiologically complex problem which is frequently not economically correctable in field crops (Jones, 1976). Differential susceptibilities to this disorder have been found among genotypes of many plant species, including soybeans (Brown *et al.*, 1972), sorghum (Brown and Jones, 1975a), and weeping lovegrass (Foy *et al.*, 1974c). Certain weeping lovegrass strains that are most susceptible to Fe deficiency chlorosis on calcareous soils at pH 7.8 show greatest tolerance to acid mine spoils at pH 3.5. Conversely, the strains most resistant to chlorosis on calcareous soil died on mine spoil at pH 3.5 (Foy *et al.*, 1974c). Plant genotypes within species also differ widely in their tolerance to salinity (Poch and Epstein, 1976), excess non essential and essential metals (Brown *et al.*, 1972; Brown and Jones, 1975), and low levels of P (Clark and Brown, 1974; Salinas and Sanchez, 1976), Mg (Clark, 1975a), N (O'Sullivan *et al.*, 1974) and micronutrients (Brown *et al.*, 1972; Brown and Clark, 1974; Wann, 1975).

Figure 2. Differential lime responses of two grass species on acid Al toxic Tatum soil. (Left) weeping lovegrass and Ky 31 fescue with no lime, pH 4.3. (right) same species with 3,000 ppm $CaCO_3$, pH 5.5.

Figure 3. Differential tolerances of weeping lovegrass (top) and Ky. 31 fescue (bottom) to Al^{3+} in nutrient solutions at initial pH 4.5 (left to right: 0, 1, and 4 ppm Al added). (Fleming *et al.* 1974)

MECHANISMS OF TOLERANCE TO MINERAL STRESS

Aluminum Toxicity

Aluminum-tolerant varieties of wheat, barley, and rice, and inbred lines of corn, increase the soil or nutrient solution pH of their root zones and thus decrease the solubility and toxicity of Al. In contrast, Al-sensitive varieties of the same species lower the pH of their root zones and thus increase Al toxicity (Foy, 1974a). Differential Al tolerance among varieties of peas has also been associated with such pH changing abilities (Khmachevskii and Berezovskii, 1973). Aluminum-tolerant varieties of wheat and barley have lower root cation exchange capacities, lower Al accumulation by roots (but not by tops), less interference by Al in root cell division, and a greater resistance to Al-induced Ca-deficiency (rolled young leaves) in plant tops as compared with Al-sensitive varieties (Foy, 1974a). Howeler and Cadavid (1976) found that Al-tolerant cultivars of rice had higher levels of both P and Ca and lower levels of Al in their shoots than Al-susceptible cultivars.

Aluminum-tolerant soybean varieties are more resistant to a petiole collapse that has been attributed to an Al-induced decrease in Ca transport (Foy, 1974a). Differential Al-tolerance in Dade and Romano snapbean varieties was not associated with differential pH changes in root zones nor with Al concentrations in plant tops or roots. The Al-tolerant Dade variety produced more stem exudate and the exudate contained higher Ca concentrations than that of the Al-sensitive Romano variety in the presence of Al (Foy, 1974a). This increased Ca uptake by the Al-tolerant Dade variety was found in whole plant tops, in stem exudate, and in the cell walls, mitochondria, and supernatant fractions of root homogenates.

Aluminum tolerance in certain varieties of wheat, barley, and inbred lines of corn has been associated with their ability to tolerate low levels of P in the growth medium, either in the presence or absence of Al (Foy, 1974a; Foy *et al.*, 1973b). In certain inbred lines of corn, Al tolerance is associated with greater Mn efficiency (Clark, 1975b). Certain Al-tolerant wheat genotypes (Fleming, 1975) and corn inbred lines (Clark, 1975a) have higher activities of root phosphatases than Al-sensitive genotypes of the same species.

In plants in general, Al has been reported to interfere with cell division in roots, fix P in a less available form in the soil and on root surfaces, decrease root respiration, interfere with certain enzyme reactions governing the deposition of polysaccharides in cell walls, and interfere with the uptake, transport, and use of several elements, including Ca, Mg, and P by certain plants (see review by Foy, 1974a for original references). Besides preventing or decreasing P uptake from external sources, Al in roots has been reported to extract P from adjacent root cells and tissues and thus form a sink for plant P absorbed from other sites (Stryker *et al.*, 1973). Aluminum tends to accumulate in or on the roots of injured plants, frequently in association with P (McCormick and Borden, 1974), but is not generally translocated to the tops. Recently, Matsumoto *et al.* (1976) reported that in pea roots Al was localized in the epidermis and regions where cells actively divided, such as root tips and differentiating lateral roots. Within cells, the Al accumulated mainly in the nuclei and cell walls. Molecular sieving chromatography indicated that Al^{3+} in nuclei acids,

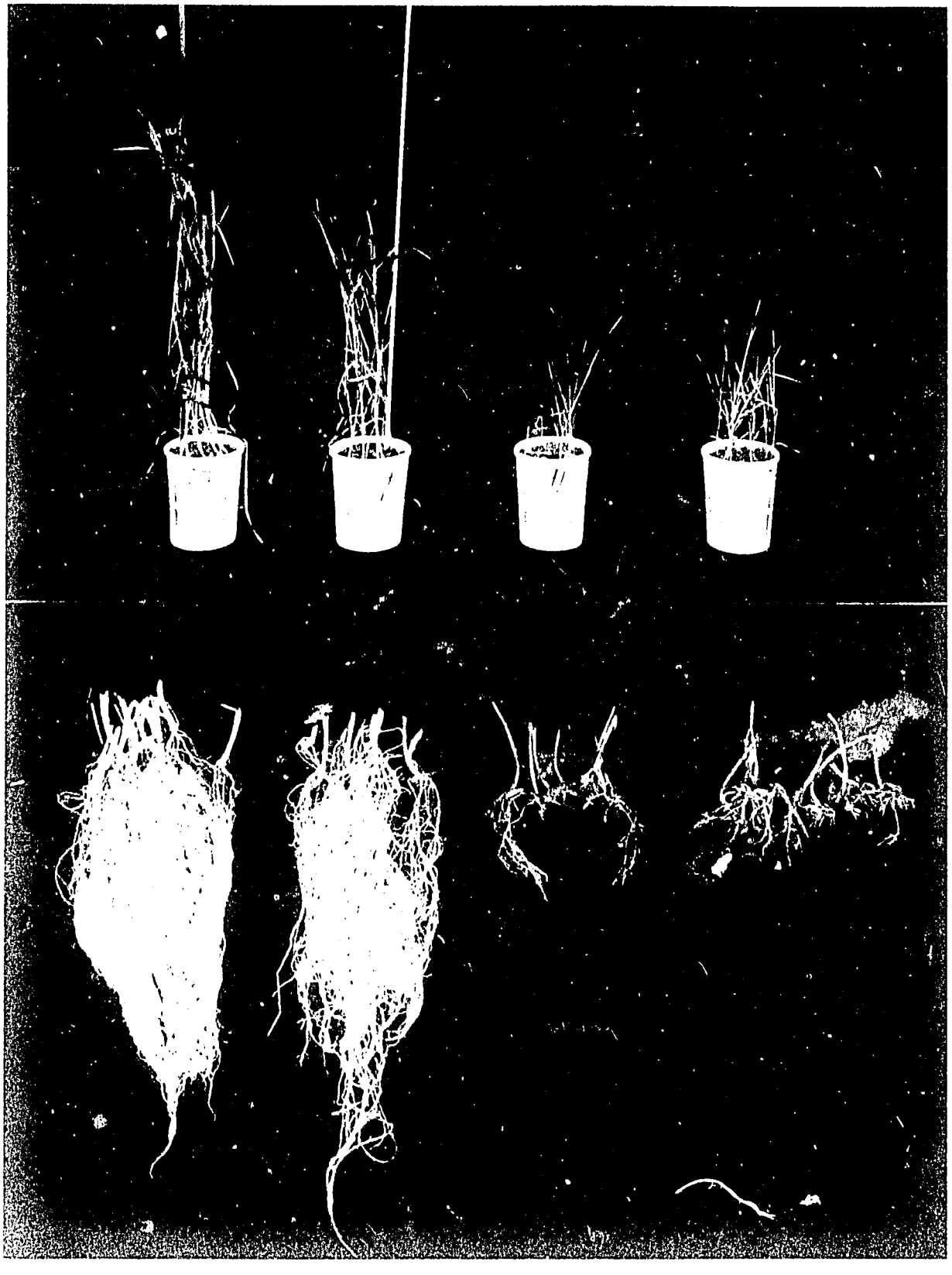

Figure 4. Differential tolerances of four wheat genotypes on Al toxic unlimed Bladen soil at pH 4.0 (Left to right) Thorne 1623, 1662, and Redcoat (Foy *et al.* 1974)

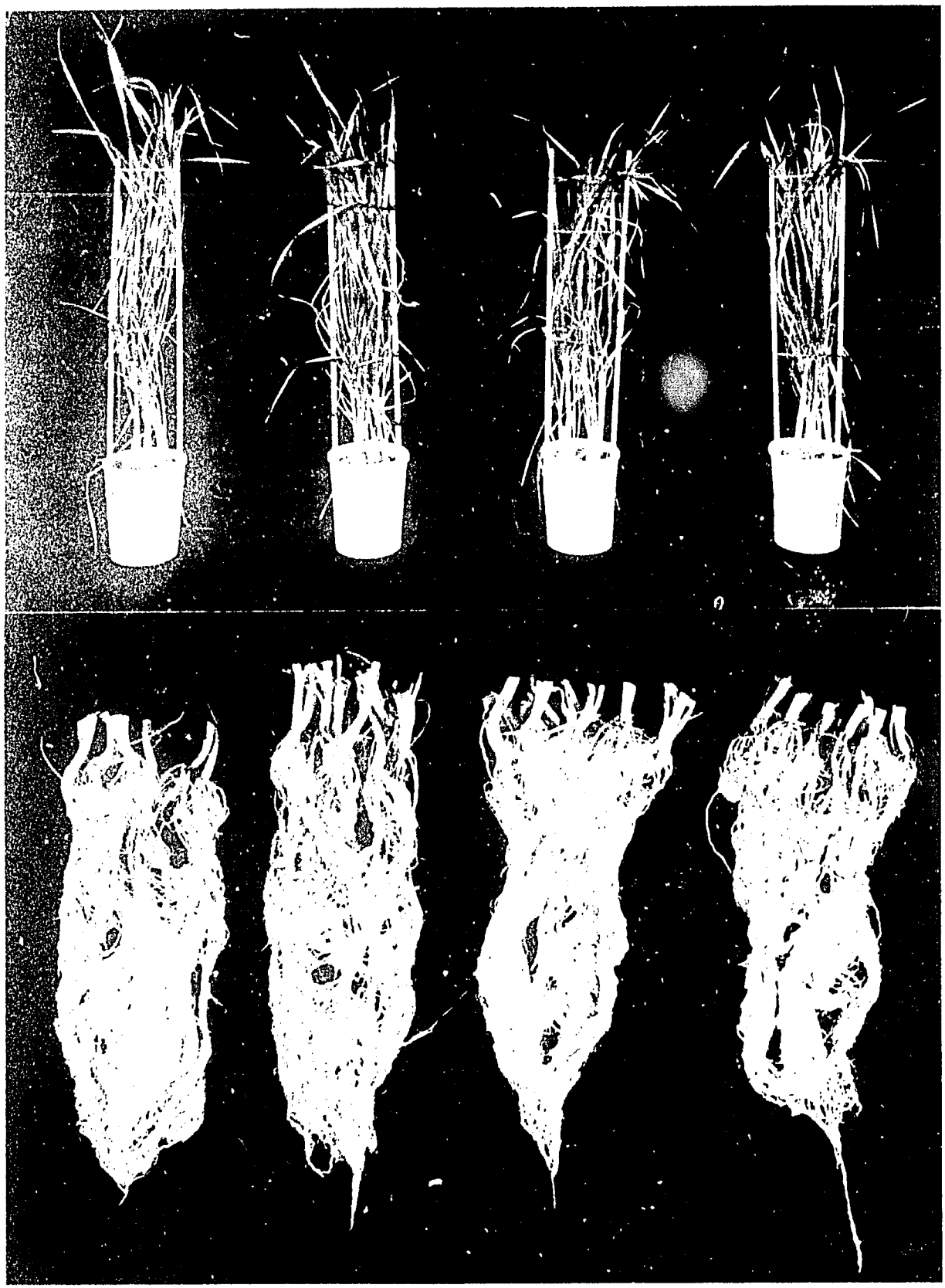

Figure 5 Growth of four wheat genotypes on Bladen soil with 3 000 ppm $CaCO_3$ added, pH 5.90 (Left to right) Thorne, 1628, 1662, and Redcoat (Foy *et al.*, 1974)

associated preferentially with DNA. The effects of Al discussed in this paragraph did not involve varietal comparisons, but they suggest research approaches for determining the biochemical mechanisms of differential Al tolerance. For additional details on the subject, see Rorison (1972) and Foy (1974a).

Manganese Toxicity

Manganese tolerance has been attributed to reduced Mn absorption, less translocation of Mn to plant tops, and/or greater tolerance to high internal levels of Mn within plant tops (Foy, 1973; Foy *et al.*, 1973a). The superior Mn tolerance of rice (as compared with soybean) coincides with a greater ability of roots to oxidize Mn from the divalent (available) form to the tetravalent (unavailable) form (Doi, 1952; Engler and Patrick, 1975). Bromfield (1976) reported that an alga, tentatively identified as *Chlorococcum humicolom* (Naeg) Rabenh, can oxidize Mn at bulk soil pH levels below 5.0. In certain alfalfa clones and tropical legumes, Mn tolerance has been associated with the retention of excess Mn within plant roots (Ouellette and Dessureaux, 1958; Andrew and Hegarty, 1969). Some varieties of wheat, cotton, and soybean apparently tolerate higher internal Mn levels than others (Foy, 1973; Foy *et al.*, 1973a; Heenan and Carter, 1976). Souto and Dobereiner (1969) reported that Mn markedly decreased nodulation in tropical legumes and that Mn toxicity varied between varieties within plant species.

Some general effects of Mn toxicity in plants, not involving varietal comparisons, are listed below. These may be helpful in devising research approaches to clarify the biochemical mechanisms of tolerance. In cotton, Mn-toxicity has been associated with a destruction of auxin (IAA) by stimulating the activity of IAA oxidase (Morgan *et al.*, 1966). Stonier *et al.* (1968) reported that excess Mn catalyzed the oxidation of auxin protectors in Japanese morning glory. Sikar and Amin (1974) found that Mn-toxicity in cotton was related to elevated activities of peroxidase and polyphenol oxidase and lower activities of catalase, ascorbic acid oxidase, glutathione oxidase, and cytochrome-C oxidase. High Mn tissues also had lower contents of ATP and lower respiration rates. In Irish potatoes, Mn toxicity was decreased by treating them with six of ten amino-acids tested (Robinson and Hodgson, 1961). This suggests that Mn interferes with the synthesis or activity of one or more of these protein precursors.

Higher-than-normal levels of Mn in *Scopolia sinensis* (1 900 μg/g) increased the replication of potato spindle tuber virus RNA (Singh *et al.*, 1974). Thus mineral toxicities may well serve as predisposing factors in many plant diseases. This field deserves much more intensive study.

There is considerable evidence that Si can protect plants against Mn toxicity. Lewin and Reimann (1969) reported that Si-deficient plants accumulated higher concentrations of Mn than Si-sufficient plants and that Mn oxidation was greater in plants supplied with Si than in the deficient plants. Silicon is also known to prevent the formation of necrotic spots of high Mn concentration on barley leaves, without reducing the overall uptake of Mn (Williams and Vlamis, 1957).

Nutrient Element Efficiency

Some plants adapt to growth media with low levels of available nutrients by modifying their physiological responses. A good example of such a "stress response" is that of soybeans grown on calcareous soils low in available Fe (Brown *et al.*, 1972). When grown on such soils, the Fe-efficient Hawkeye soybean decreases the pH of its growth medium and produces a "reductant" which converts Fe^{+++} to Fe^{++}; both processes make Fe more available and the plant remains green. By contrast, the Fe-inefficient PI 54619-5-1 soybean cannot produce this "stress response" and hence becomes Fe deficient and chlorotic.

An Fe-efficient strain of weeping lovegrass that grows well and remains green on a calcareous soil at pH 7.8 does not develop chlorosis in nutrient cultures with low levels of Fe. It maintains a lower pH in solution cultures than does a chlorosis-susceptible strain. The Fe-efficient strain dies on a mine spoil at pH 3.5, but an Fe-inefficient (chlorosis susceptible) strain survives under the same conditions (Foy *et al.*, 1974c).

Plant physiological properties, associated with specific tolerances to mineral stresses, may be useful tools for screening large plant populations. Plant varieties, differing in tolerance to mineral stress, are also valuable as indicators of potential toxicities or deficiencies in soils, and as tools for studying the complex mechanisms of plant adaptation to various stresses in soils.

GENETIC CONTROL OF TOLERANCE TO MINERAL STRESS

Aluminum tolerance in certain barley populations is controlled by one major dominant gene (Reid, 1975). One degree of Al tolerance in certain wheat populations has also been reported to be under single gene control (Kerridge and Kronstad, 1968); however, preliminary studies with other wheat populations by H. N. Lafever and L. G. Campbell, Wooster, Ohio (personal communication), indicated that Al tolerance in wheat is not inherited simply; two or possibly three genes, plus modifiers, may be involved. In Atlas 66 wheat, an Al-tolerance factor has been located on chromosome 5-D (Prestes *et al.*, 1975). Howeler and Cadavid (1976) suggested that Al tolerance in rice may be regulated by only a few genes. Differential Al tolerances of wheat and

barley varieties, demonstrated in greenhouse or growth chamber experiments (soil and nutrient solution) have been confirmed by grain yields in field plots (Foy, 1974a). There is no evidence to date that Al tolerance is necessarily associated (genetically linked) with low yield potential in the absence of Al.

In alfalfa, Mn tolerance has been attributed to additive genes having little or no dominance (Dessureaux, 1959). Efficiencies for Fe, B, N, P, and K are also genetically controlled in certain plants (Brown *et al.*, 1972; O'Sullivan *et al.*, 1974; Wann, 1975).

DEVELOPING STRESS-TOLERANT PLANT VARIETIES

The observation that tolerance to mineral stress is genetically controlled suggests that plants may be tailored for adverse soil conditions that are not economically correctable by conventional means.

A plant-breeding approach has a tremendous potential for solving some of our more difficult soil managemen. and plant nutrition problems. Aluminum-tolerant varieties are needed: (1) for deeper rooting and, hence, greater drought tolerance in strongly acid subsoils; (2) for use in vast, acid-soil regions where Al toxicity and P-fixation are major growth limiting factors (Campo Cerrado Region of Brazil and Llanos Region of eastern Colombia, Salinas and Sanchez, 1976); (3) for strongly acid soils on steep slopes that are difficult to lime; and (4) for use where even the surface soils must be kept rather strongly acid (pH 5.2 or lower) for disease control (potato scab in barley-potato rotations in eastern Canada and sugarbeet-potato rotations in Maine). Plants with high tolerance to Mn, Al, and other metals are also needed for revegetation of strongly acid mine spoils and other disturbed land.

Evidence is increasing that Al-tolerant plants can use low levels of P more effectively than can Al-sensitive plants, either in the absence or presence of Al. Thus, plants bred for Al tolerance may be more efficient P feeders on strongly acid soils (below pH 5.5) where Al limits growth and also in soils that have been limed to pH 5.5 or above, where Al toxicity is not involved. Weeping lovegrass, an Al-tolerant species, makes good use of rock phosphate on mine spoils with an initial pH of 4.0. Rock phosphate is being seriously considered for direct application to acid soils in the tropics.

Our present crop varieties have been developed with little direct attention to soil properties, because it was assumed that the soil could be economically fertilized and limed to some "optimum" level for plants in general. However, it is now clear that in spite of efforts to make the soil "ideal" for plant breeding test sites, certain plant varieties do reflect the soils (particularly the subsoils) on which they were developed. Furthermore, moving varieties from one soil to another can result in new problems of mineral element toxicity or deficiency. For example, Dayton barley, selected at Wooster, Ohio, where acid soils and Al toxicity in plants occur, is much more tolerant to Al than Kearney barley, developed in the Kansas-Nebraska area where acid soils are less common (Foy, 1974a). Seneca and Thorne wheat varieties, developed at Wooster, are more Al-tolerant than Indiana varieties (Redcoat, Arthur 71, Abe, and Monon) developed only about 480 km west on different soils (Foy *et al.*, 1974a). The Brazilian wheat varieties, Toropi and BH 1146, are even more Al-tolerant than Thorne from Ohio (unpublished data). Rex smooth-leaf cotton, developed on the acid, high Mn loessial terrace soils of Arkansas, is more tolerant to excess Mn than Coker 100A, developed on the sandy, low Mn, Coastal Plains soils of South Carolina (Foy, 1973).

We should now make a conscientious effort to select or breed plants for greater tolerance to specific mineral soil stresses that are not economically correctable. In some cases, changing the plant to fit the soil may be more economical ultimately than changing the soil to fit the plant. Such research requires a team approach. Multidisciplinary teams should be formed and plant-germplasm banks should be created, maintained, and made available to all nations. To manage both plant and soil for maximum returns, we also need to determine the physiological and biochemical mechanisms by which plants tolerate or adapt to adverse soil conditions.

The proposed plant genetic or selection approach to soil fertility problems may result in several benefits: (1) increased yields of present species on present acreage by using tolerant varieties; (2) extended acreage of sensitive species to land previously considered unsuitable to the crop (acreage of Al-sensitive alfalfa and barley might be extended by Al-tolerant cultivars); and (3) gradual improvement of soil productivity by the introduction of plants with more exacting growth requirements and, perhaps, higher yield and quality. A genetic approach does not mean the elimination of fertilizers and lime. Instead, it advocates a more effective use of plant diversity in the management of problem soils.

The plant-breeding approach to soil fertility discussed in this paper has been directed mainly toward increasing crop yields on problem soils. However, even when yields are already at a satisfactory level a similar approach may be useful in regulating the mineral composition of plants and thereby improving their quality as food for animals and man (Hill and Guss, 1976).

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DISCUSSION

Douglas Perry (Virginia, USA). Did you analyze the solution in which plants increased the pH to see what organic acids or other compounds were in the root exudate?

Foy. No, but we plan to do some work of this nature in the near future. Dodge and Hiatt (*Agron. J.* 64:476–77, 1972) associated such differential pH change with differential cation-anion uptake. Plant uptake of NO_3 causes the solution pH to increase, presumably by release of OH^- or HCO_3 from roots; NH_4^+ uptake decreases the solution pH by release of H^+ from roots. Plants fed exclusively with NH_4^+-N lower the solution pH to 3.5, and both Al-tolerant and sensitive cultivars are injured or killed. When the ⅕ Steinberg solution contains 10–18% of the total N as NH_4^+, the Al-tolerant wheat cultivars raise the pH and sensitive cultivars either lower or fail to raise it. Such differences could result from differential NO_3 uptake and use, as suggested by Dodge and Hiatt. Aluminum-tolerant plants may have more active nitrate reductase systems. The pH decreases in solution by Al-sensitive cultivars could be caused by the excretion and ionization of organic molecules.

Jones (*Plant and Soil* 13:297–310, 1961) suggested that organic acids in Al-tolerant plant species chelate Al and thus prevent the Al-P precipitation which normally occurs in plant roots at physiological pH levels. Small (pH and Plants, Bailliere, Tindall and Cox, London, 1946; *Plant Physiol.* 24:75–83, 1949) pointed out that acid-tolerant plants generally have strong organic acid buffer systems, in contrast to acid-sensitive plants in which phosphate buffers dominate the system. Aluminum-sensitive barley is known to have a phosphate type buffer system. In such plants Al precipitates with P in the roots but does not generally accumulate in plant tops. In fact, Al accumulation in plant tops (< 1000 ppm) is associated with Al tolerance, rather than sensitivity (*Tea Quarterly* 43:4–13, 1972; *New Phytol.* 76:551–54, 1976).

We need to characterize the root exudates of Al-tolerant and sensitive genotypes more thoroughly. Phosphate metabolism is almost certainly involved in Al tolerance. Some Al-tolerant cultivars appear to have higher root phosphatase activities than those of Al-sensitive ones.

The physiology of differential Al and Mn tolerance in plants will be reviewed in greater detail in a paper to be presented at the ASA Meetings in Houston, Texas, November 28–December 3, 1976.

Tony Bradshaw (Liverpool, England). What is known about genetic control of Al and Mn tolerance in plants?

Foy. Aluminum tolerance in certain barley populations is controlled by one major dominant gene (D. A. Reid—*Barley Genetics II*, pp. 409–13, 1969). At least one degree of Al-tolerance in certain wheat populations has also been reported to be under single gene control (Kerridge and Kronstad, *Agron. J.* 60:710–11, 1968). However, preliminary studies with other wheat populations (H. N. Lafever and L. G. Campbell, Wooster, Ohio) indicate that Al tolerance in wheat involves two or three genes, plus modifiers. Tolerance to Mn toxicity in alfalfa has been attributed to additive genes having little or no dominance (Dessureaux, *Euphytica* 8:260–65, 1959). Genetic-biochemical studies on differential Al and Mn tolerance are just beginning. The Al-tolerance gene in barley may promote the synthesis of a certain enzyme protein (or an allosteric form of the same enzyme) which is resistant to attack by Al or more efficient in promoting the metabolism of P or other essential elements in the presence of Al.

92.
Specialty Crops—An Alternate Land Use on Surface Mine Spoil*

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We know that with good management practices and proper application of soil amendments, high-quality grass and legume forages can be established and maintained on surface mine spoil (Jones *et al.*, 1973 and 1975). In addition to meeting stabilization and conservation objectives, however, we need land uses for "minesoils" that have economic potential. High-value horticultural crops offer diversification and an opportunity to increase food production in Appalachia. In this coal-producing area, only 10 to 20% of the mountainous land surface can be used for agriculture (Gorman and Espy, 1975). Therefore, each man-made hectare gained from surface mining should be used to its fullest potential. The area has adequate rainfall, averaging over 100 mm for each month of the 140-day growing season from May to September.

The physical and chemical properties of minesoils largely determine how they can be used. However, organic matter content can be increased through the use of forage species, green manure crops, and rotations (Jones *et al.*, 1975). Water infiltration and use efficiency can be improved by using mulches of straw, wood chips, or sawdust. Likewise, mulches grown in place and used with no-tillage techniques not only conserve soil water, but also increase profile organic matter.

Many surface mining operators now feel that reclamation is just as much their business as is the extraction of coal. Some operators and landowners are eager to go beyond the legal requirements for stabilization of minesoils to a preplanned future use offering economic value. Several coal companies have pilot programs for growing grapes, apples, peaches, and blueberries. The literature, however, contains little information on food crop production on surface minesoils. In Illinois 5519 kg of field corn/ha were produced on a mined area that had been in alfalfa, sweet clover, and bromegrass for five years (Higgins, 1973). Average corn grain yields from a corn, corn, oats, alfalfa rotation ranged from 4077 to 4390 kg/ha. In Czechoslovakia 9800 kg of white potatoes/ha were produced on a minesoil that had been seeded to a clover-grass mixture for four years. In the sixth year the yield of ensilage corn was 53800 kg/ha (Frantisek, 1973).

The purpose of this study was to determine the feasibility of vegetable production on minesoil, and evaluate the inflaence of fertility levels and mulches on yield. This paper reports that sweet corn, horticultural beans and tomatoes can be successfully grown on a reclaimed surface mine spoil.

MATERIALS AND METHODS

The field studies were located on a regraded surface mine bench area at White Oak Mountain in south-central West Virginia (37°40′N; 81°W; 800 m above sea level). The entire area is mountainous. The undisturbed soil surrounding the bench area is classified as Dekalb (Typic Dystrochrepts; loamy-skeletal, mixed, mesic) and Gilpin (Typic Hapludults; fine-loamy, mixed, mesic) formed in acid material weathered from sandstone and very stony. Slopes range from 40 to 70% and coarse fragments make up more than 35% of the acid profile (Gorman and Espy, 1975). In 1970, following extraction of the coal, the pH of the freshly regraded bench area ranged from 3.8 to 4.2. Plant cover consisted mainly of Ky 31 fescue (*Festuca arundinacea*) and sericea lespedeza (*Lespedeza cuneata*) until the area was turnplowed in the spring of 1975. Improvement in pH was noted with values ranging from 5.0 to 5.2.

Vegetable crops grown in 1975 and 1976 were sweet corn (*Zea mays*, "Golden Cross Bantam"); bush horticultural beans (*Phaseolus vulgaris*), commonly known as October beans; and tomatoes (*Lycopersicon esculentum*, "Big Boy," "Supersonic," and "Manapal"). Each year after plowing, the seedbed was prepared with a spring tooth harrow. Soil amendments applied were incorporated 7.5 to 10 cm deep with a rototiller. Application of lime (54% $CaCO_3$ + 43% $MgCO_3$) was made only in 1975. In the sweet corn and bean studies it was applied by treatments. In the tomato study a blanket application of lime was broadcast on the entire plot area. The source of fertilizer was a commercial 10-10-10 analysis. Treatment rates were broadcast and incorporated prior to establishment of each crop. A mulch variable

*Contribution from ARS-USDA and the agricultural experiment stations of Virginia and West Virginia. Research funded, in part, by the U.S. Environmental Protection Agency.

compared no mulch with straw in the corn study, sawdust in the bean study, and both straw and sawdust in the tomato study. Mulch residues from the 1975 studies were plowed down. The same experimental design and field plot location were used each year.

Corn Study

Lime and fertilizer treatments are shown in Fig. 1. A randomized split-plot design was used with three replicates. Main plots (4.6 by 12.8 m) were assigned to the lime levels and mulch variable. Subplots (4.3 by 4.6 m) were assigned to fertilizer treatments. The corn was planted using the wheel-track-plant technique with a row spacing of 106 cm. Replanting was done by hand to provide uniform stands. Weeds were controlled by hand methods. Straw mulch was applied at the rate of 9 MT/ha. Mature corn plant heights (leaves extended) for 20 random plants/plot were measured from ground level. At silking, random leaf samples (first leaf below the ear) were collected, dried at 65 C and ground in a Wiley mill. At harvest, the number of ears produced and ear weights (husks included) were recorded from the entire plot.

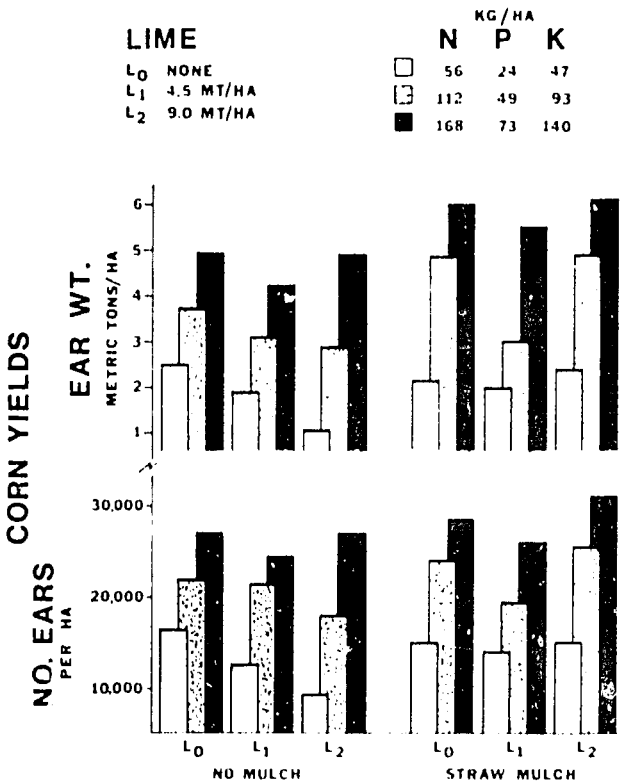

Figure 1. The influence of lime, fertilizer and mulch on the number and weight of sweet corn ears produced on surface mine spoil.

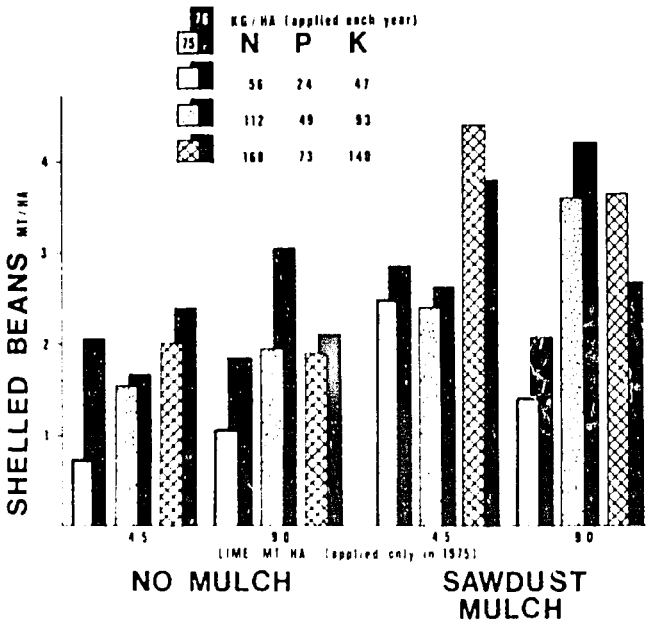

Figure 2. The effect of lime and fertilizer rates on horticultural bean yield with and without a mulch in 1975 and 1976.

Bean Study

Twelve treatments were used in a randomized block design. Individual treatments, as shown in Fig. 2, included variables of fertilizer, lime, and mulch. Plots were 4.3 by 4.6 m. Planting procedures were the same as those used in the corn study, except row spacing was 53 cm. Replanting and weeding were by hand. Sawdust mulch was used at the rate of 44.8 MT/ha (about 2.5 cm deep). Random leaf samples of mature bean leaves were collected from the top of the plants after flowering. Samples were processed for analyses as indicated in the corn study. Harvest was made on four central rows for a total length of 12.2 m. Yield was recorded as shelled fresh beans (high moisture, 35 to 50%).

Tomato Study

Lime was broadcast at the rate of 11.6 MT/ha on the entire plot area to bring the pH to about 6.8. Fertilizer and mulch treatments for each variety are shown in Fig. 3. A randomized split-plot design was used with three replicates. Main plots (4.3 by 4.6 m) were assigned to the fertilizer and mulch variables. Subplots were 1.4 by 4.6 m for each of the tomato varieties. Greenhouse grown plants were transplanted on a 1-m spacing in the row. They were staked and pruned to allow two dominant stems per plant. Both straw (9 MT/ha) and sawdust (44.8 MT/ha) were used as mulch. Random mature leaf samples were collected at a height of 50 cm above the ground level when the first fruit ripened. Samples were processed for analyses as in the corn and bean study. Fruit yield from each subplot (five plants)

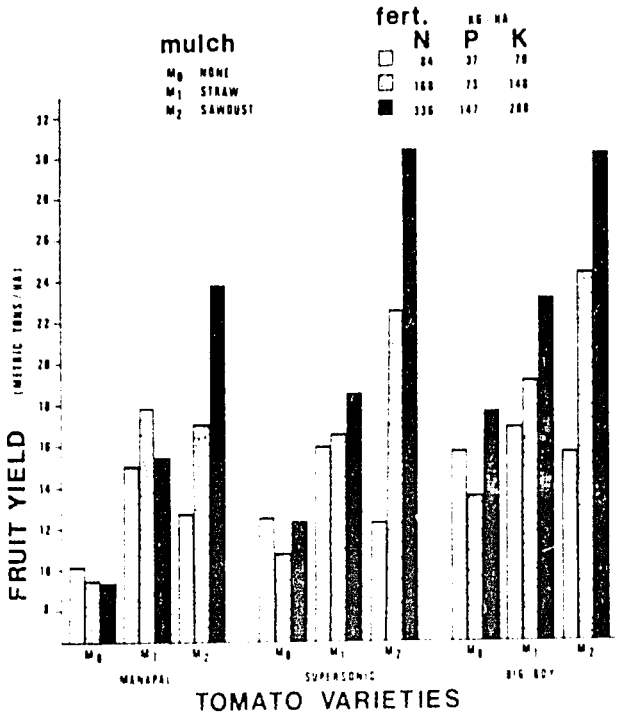

Figure 3. Two-year mean tomato fruit yield comparisons from three varieties, fertilizer levels and mulches.

was recorded at each harvest, but the percentage of marketable fruit was not determined.

For each crop, yield and leaf element content were the primary data obtained. Element uptake was determined by emission spectrography. After the killing frost on September 14, all three plot areas were disked and drill-seeded with rye (*Secale cereale*) which served as the winter cover crop. Soil samples were taken after overwintering. Soils data were obtained by using standard soil testing procedures. Only soil organic matter content, pH, and available CaO are reported since P and K differences among treatments were small.

RESULTS AND DISCUSSION

Weather conditions and rainfall distribution for the two growing seasons were quite different. Considerable soil water stress existed in 1975, as rainfall for the period June through September 14, when a killing frost occurred, totaled only 263 mm. This was below the normal average of 100 mm per month. Factors which influenced plant growth and yield were moisture stress and nitrogen uptake. In 1976, precipitation for the May-September period totaled 469 mm. Increased availability of plant nutrients under the near normal soil moisture conditions was the contributing factor to increased plant growth and yields in the second season.

Sweet Corn

Plant height in 1975 was decreased by periods of moisture stress. The average height of the unmulched corn was only 138 cm as compared with 163 cm for the straw-mulched corn. The number of ears produced and ear weights (Fig. 1) reflect somewhat the effect of mulch, but primarily show response to the three levels of N, P, K fertilizer applied. The highest ear yield was 30744 ears/ha, which weighed 6.2 MT. This was produced under straw mulch at the highest fertility and lime levels. The analysis of variance on yield indicated a difference in weights for the mulch treatments at the 0.05 level and for the fertility treatments at the 0.01 level. Mean yields were different for the low, intermediate, and high fertilizer levels, and were 2.1, 3.8, and 5.3 MT/ha, respectively. Lime had no significant effect.

In 1976 no yield data were obtained from the sweet corn study. The plot area had to be replanted twice before a satisfactory stand was obtained. The third planting, due to the mid-July planting date and high plant population, produced only imperfect, small ears (nubbins).

Horticultural Beans

Yields from the 1975 and 1976 seasons exhibited similar treatment trends (Fig. 2). Yield increases obtained in 1976 were probably due to the more normal rainfall. The yield decrease from the high fertility level under sawdust in 1976 was not expected. From the analysis of variance, lime rate had no significant effect, but sawdust mulch and fertility levels did. The highest shelled bean yield of 4.3 MT/ha was obtained in 1975 with the 4.5 MT/ha of lime, the high fertility level, and with sawdust mulch. Two-year mean yields for the low, medium, and high fertilizer treatments, with and without mulch were: 2.2, 3.2, 3.6, 1.4, 2.1, and 2.1 MT/ha, respectively. Yield increases of 50 to 70% resulted from the use of sawdust as a mulch.

Tomatoes

Mean yields from the 1975 and 1976 growing seasons shown in Fig. 3 reflect variety response to mulch and to the three levels of fertilizer. The highest fruit yield from each variety was produced with sawdust mulch and the highest fertility level. The analysis of variance indicated that the effects of mulch, fertilizer levels, and varieties were highly significant (0.01 level). Mean yields were 12.3 MT/ha with no mulch, 17.6 with straw mulch, and 20.8 with sawdust mulch. Big Boy yielded an average of 19.3 MT/ha as compared with 16.9 and 14.5 MT/ha for Supersonic and Manapal. The intermediate fertilizer rate produced an average of 16.7 MT, which was not significantly lower than the yield of 20.0 MT from the high rate or significantly higher

TABLE 1. Element concentrations (overall treatment means) in leaf and fruit plant tissue[a] for the various vegetable crops grown in 1975

Vegetable Crop	Plant Tissue Sampled	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Sr	Ba	Na
		Percent					*ppm*								
Tomato	Young mature leaf	4.0	.22	4.7	1.9	1.3	620	184	10	19	167	123	13	12	352
	Fruit	3.3	.46	2.5	.14	.21	63	75	10	14	42	52	<4	<6	81
Sweet Corn	Ear leaf after silking	2.1	.31	3.3	.31	.37	190	139	6.3	7.0	53	17	3.5	3.8	190
	Ear	2.4	.46	1.5	<.05	.17	37	36	6	10	39	22	<4	<6	50
Beans (October)	Young mature leaf	3.2	.54	2.3	2.1	.84	771	405	39	8.5	94	257	24	29	210
	Mature moist bean	3.0	.63	2.0	.07	.18	66	85	11	14	47	<18	<4	<6	50

[a]Dry matter.

than the 13.9 MT produced from the low rate.

Elemental concentration in leaf tissue and edible fruit of the vegetable crops grown in 1975 are given in Table 1. Although significant differences existed for the variables of mulch, fertilizer, and species among the various nutrient elements, most values were considered to be within a normal range. Concentrations found in "normal" plants or established sufficiency ranges were used as guidelines for a comparison with these vegetable crops (Geraldson, Kiacan, and Lorenz, 1973; Giordano and Mays, 1976). The phosphorus sufficiency range for young, mature tomato leaves is 0.8–1.0%. In our study the overall mean of 0.22% P indicated a deficiency. Mean values for all other principal nutrients were within the sufficiency range. The normal values for Zn, Cu, and B in fruit are 25–30, 5–8, and 1–10 ppm, respectively. As seen in Table 1, data values were 42, 14, and 10 ppm for these heavy metals. Element content in sweet corn leaves was influenced by fertility level. For this crop only N was below the sufficiency range of 2.6–3.5%. Data values for Zn and Cu of 39 and 10 ppm compared favorably with normal values of 40 and 6 ppm. Bean leaf element content was influenced by fertility levels, with significant differences for N, P, and K; however, the overall means were within the sufficiency range. Based on the normal nutrient range, amounts of Mn and Zn in the bean leaf tissue were excessive. Toxic effects above 60 ppm of Zn caused some yield reduction (Giordano and Mays, 1976). Data values of 47 and 14 ppm for Zn and Cu in the beans were near the normal values of 45 and 9 ppm.

Organic matter and pH are of prime importance in the development and potential utilization of minesoils. Soil test results of profile samples taken from the experimental sites are given in Table 2. The sod of sericea lespedeza and Ky 31 fescue was effective in building organic matter, and the addition of straw or sawdust mulch used in the vegetable studies in some cases further increased the organic matter content. Accumulations in the minesoil from the previous 4.5 years under forage grasses averaged 1.85, 1.45, and 1.33% for the 0 to 7.6 to 15 and 15 to 25-cm profile depths, respectively (Jones *et al.*, 1975).

TABLE 2. Organic matter content and pH status of the cropped minesoil following overwintering

Previous Crop	Sample Depth (cm)	Available CaO (kg/ha)	pH	Organic Matter Content (%) No Mulch	Straw Mulch	Sawdust Mulch
Tomatoes	0–7.6	2 950	7.08	1.85	1.91	3.11
	7.6–15	920	5.16	1.70	1.76	1.73
	15–23	800	4.99	1.74	1.59	1.82
Corn	0–15	1 040	5.48	2.47	2.29	—
		1 620	6.25	2.54	2.34	—
		1 840	6.55	2.30	2.46	—
Beans	0–15	1 110	5.83	2.17	—	2.59
		1 460	6.44	2.61	—	2.39

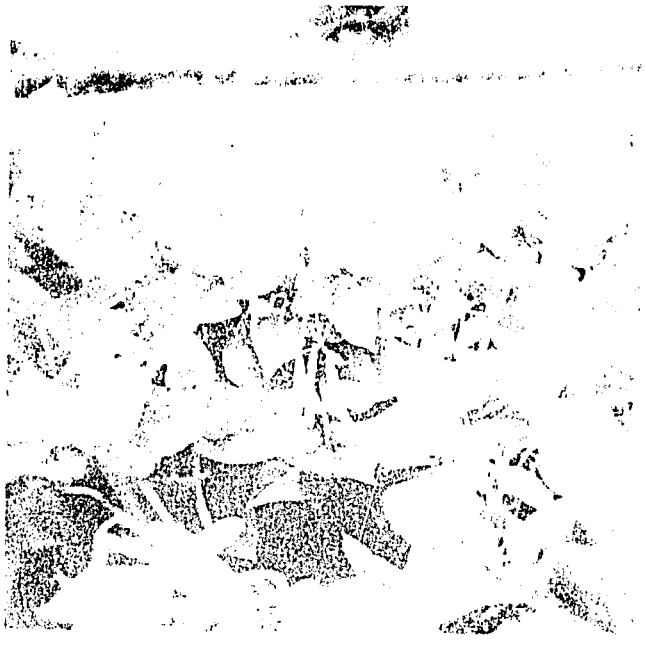

Figure 4. Upper left—horticultural bean study; upper right—sweet corn experiment; lower left—tomato study. Located on minesoil bench area, White Oak Mountain, West Virginia.

This preliminary test of growing sweet corn, October beans, and tomatoes (Fig. 4) on surface minesoil, shows that good management plus the addition of adequate primary nutrients and mulch are required for satisfactory vegetable growth. Yield data indicate that this use of minesoil does offer potential and a challenge. With time, physical structure can be improved and available water capacity of minesoils can be increased. Landowner use of other than stabilization species will be determined by the need and economic returns derived from growing selected high value cash crops.

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94.
Reclamation Technology Training in the United States

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As the nation and world turn to coal as a solution to the energy shortage, there is an increasing need for field technicians having a wide variety of specialized skills and some advanced education specifically in the science of strip mine reclamation. This need is being met by graduates of two-year reclamation technology programs.

Up to now, individuals specifically trained in the science and art of reclamation technology have been scarce. The demand for trained personnel to solve strip mine reclamation problems has been partially satisfied by professionals with degrees in engineering, agronomy, geology, and forestry. Since strip mine reclamation is a multidisciplinary science, there is a need for integrating resource management techniques of the different environmental specialities. Many professionals, when working in reclamation, find themselves somewhat handicapped in that their formal education did not include integrated resource management training. Thus, the need for specialized reclamation training which incorporates a multidisciplinary approach was soon identified.

DUTIES OF A RECLAMATION TECHNICIAN

Generally speaking, a person with an associate degree in Reclamation Technology has received multidisciplinary training which includes instruction in engineering, forestry, geology, agronomy, chemistry, hydrology, agricultural plant sciences, reclamation practices, reclamation laws and regulations, aerial photo interpretation, and soils. In addition, a liberal arts education is recommended for a well-rounded program. This training prepares individuals for field positions with coal companies, government agencies, reclamation associations, and consultants.

Reclamation technicians assist in preplanning, which includes analyzing the geology of the area to be mined and planning spoil bank placement to facilitate reclamation. They also supervise spoil grading to control surface water drainage.

Collection, laboratory analysis, and interpretation of spoil, water and overburden samples are important job functions. The reclamation technician coordinates mulching, fertilizing, liming, and planting of grasses, legumes, and trees to return mined land to pasturelands and forests. Treating acid mine drainage, planning land use, and training participating workmen are other tasks.

Many government enforcement agencies employ reclamation technicians as field inspectors. Industry, however, generally pays higher salaries than the government. Starting salaries currently range from approximately $7,000 to $16,000 per year.

Employment is not limited strictly to the field of strip mining. Any environmental disturbance that requires reclamation work falls within the job functions of a reclamation technician. This includes work on road cuts and fills, construction sites, natural catastrophe areas and on municipal, agricultural, and industrial waste sites.

COOPERATIVE EDUCATION CONCEPT

In any type of resource management training, including Reclamation Technology, there is no substitute for actual field experiences. To emphasize the practical aspect of reclamation, most of the colleges have incorporated a concept in education called Cooperative Education (also known as internships). Under this system, students alternate semesters as paid, full-time coal company or government employees, during which they work and learn, with a semester of full-time studying. Many variations of this system are used, such as placing students in work stations during the summer months instead of between regular semester terms.

The work phase of a co-op arrangement is advantageous for students in four ways: (1) they obtain actual work experience; (2) they earn money; (3) they receive college credit; (4) they make job contacts for permanent positions after graduation. Organizations that participate in a reclamation co-op or internship program benefit in that they receive personnel trained specifically in Reclamation Technology and have an opportunity to groom the students during the work phases of the program for their particular reclamation problems.

RECLAMATION TECHNOLOGY SCHOOLS

Presently, there are five ongoing associate degree programs in the nation specifically in Reclamation Technology. For the most part, they are basically similar in design and purpose in that they all bring together into one program multidisciplinary environmental training. The following educational institutions presently have associate degree programs in Reclamation Technology: Belmont Technical College, Lees Junior College, Morehead State University,

Madisonville Community College, and Southeast Community College. An in-depth discussion of the programs initiated by these schools follows:

Belmont Technical College; St. Clairsville, Ohio; degree: A.S., Land Stabilization and Reclamation

The college is chartered by the Ohio Board of Regents and is funded by the Ohio State Department of Education. Initiated in the fall of 1971, the Land Stabilization and Reclamation Program is designed to develop technicians capable of planning and supervising soil stabilization and land reclamation programs. Course emphasis is placed on field practicums and skill development, along with an academic understanding of conservation practices and concepts. Belmont Technical College has graduated 45 reclamation technicians at a rate of 12 to 15 per year and currently has an approximate enrollment of 28 to 32 students in the program

During the summer quarter, Land Stabilization and Reclamation students are involved in an internship and special problems program that provides them with an opportunity to put to practical use the knowledge obtained in the classroom. Reclamation organizations involved in the Belmont Internship program are: Consolidation Coal Company, Ohio River Colliery, Marietta Coal Company, Cramer Landscaping, Central Ohio Coal Company, Y and O Coal Company, Wheeling Park Commission, North American Coal Company, Marshall County Park Commission, Ohio Department of Transportation, and others. The student is evaluated periodically by his employer along with his adviser. In the "LS Special Problems" course, students are assigned, individually or by groups, a research project pertaining to the importance of reclaiming and developing land for various productive purposes. The seminar substitutes for part of the internship in the event a student cannot be placed during the internship period.

While cost is low at Belmont, financial assistance, in the form of grants, scholarships, and work study programs, is available for students who demonstrate a need. Day and night classes permit students flexibility of time.

Lees Junior College; Jackson, Kentucky, degree: A.S., Mining and Reclamation Technology

Initiated in the fall of 1975, this 67 semester credit hour program prepares individuals for positions as assistants to mining or highway engineers, supervisors of mining operations, and supervisors of reclamation operations and places special emphasis on surface mining methods of operation. Approximately 35 mining students are enrolled at Lees Junior College, and the first graduates are expected to be ready for employment in the spring of 1977. Lees projects 12 graduates per year.

An important aspect of the program is the Cooperative Education component. Students work on the job during the summers to gain familiarity with mining operations and the general atmosphere and attitude of the mining industry and to receive college credit as well as earn a salary. Reclamation organizations participating in the Cooperative Education Program at Lees include the Kentucky Division of Reclamation and members of the local coal industry.

Morehead State University; Morehead, Kentucky; degree: A.S., Reclamation Technology

Begun in the fall of 1975, this two-year program is designed to prepare individuals for employment in mining as well as other industrial positions where land environmental protection is a major consideration. A cooperative study course is offered during the summer, between the second and third semester.

Presently, the Reclamation Technology program at Morehead is operating on a part-time basis. Therefore, graduates from this program are not expected before the spring of 1978. When the Reclamation Technology program begins to operate on a full-time basis, it is expected to generate approximately 15 graduates per year.

Madisonville Community College; Madisonville, Kentucky; degree: A.S., Reclamation Technology

Part of the University of Kentucky Community College System, Madisonville Community College (MCC) initiated its Associate Degree in Applied Science in Reclamation Technology in the fall of 1974. Enrollment now is approximately 80.

The curriculum consists of four semesters and requires 64 semester hour credits for graduation. A total of 11 students have thus far completed the program and now are employed in the field. It is projected that 15 to 20 students per year will complete the training.

The Commonwealth of Kentucky is the only state that has strip mining in the Appalachian Coal Region as well as in the Eastern Interior Coal Region. Contour strip mining occurs in the mountains of eastern Kentucky, and area strip mining occurs in the flat lands of western Kentucky. Both regions have unique reclamation problems. MCC takes full advantage of this situation and is therefore able to conduct instruction and field exercises in both contour and area strip mining.

In the instruction at MCC, emphasis is placed on reclamation field work. A course entitled "Practicum in Reclamation Technology" is concerned with practical application of the reclamation principles, and students learn to operate the heavy equipment used in reclamation, such as bulldozers, scrapers, graders, front-end loaders, hydroseeders, straw blowers, farm tractors, etc. This is possible through

cooperative agreements with the Breckingridge Satellite Job Corp Training Center in Muhlenberg County, the Kentucky Reclamation Association, and various coal companies and government agencies scattered throughout Kentucky, Indiana, and Tennessee. The purpose of this course is not to make heavy equipment operators out of reclamation students, but rather to acquaint them with the capabilities and limitations of the equipment. This training is essential to reclamation technicians because they will be directing the activities of this type of equipment after graduation.

Reclamation students at this school have Cooperative Education opportunities not only in the western Kentucky coal region, but in reclamation co-op positions throughout the nation. Cooperative Education agreements have been worked out between MCC and the following reclamation organizations: Kentucky Division of Reclamation, Kentucky Reclamation Association, U.S. Forest Service, Tennessee Valley Authority, Kentucky Orphan Banks Program, Peabody Coal Company, Island Creek Coal Company, Amax Coal Company, and Pittsburgh and Midway Coal Company.

The Reclamation Technologists of America, initiated in the spring of 1976, is an active student organization at MCC. It has as one of its main purposes the promotion of professionalism in the practice of reclamation technology.

Southeast Community College; Cumberland, Kentucky; degree: A.S., Reclamation Technology

Southeast Community College (SCC) also is a part of the University of Kentucky Community College System. SCC began its associate degree program in Applied Science in Reclamation in the fall of 1976, and the curriculum is the same as that of Madisonville Community College.

SCC graduates approximately 10 to 12 technicians per year. At this time, the school does not yet have an ongoing co-op program. SCC does have a wide range of financial assistance programs available to students.

Other Sources of Training

In addition to the five formal training programs reviewed in this paper, reclamation training exists in the form of seminars, symposia, and interagency tours. Also, many companies and government agencies have in-house reclamation training programs for their employees, and several schools and universities across the United States offer individual night courses in strip mine reclamation or related subjects as a continuing education service.

DISCUSSION

Unidentified. Are we talking about degrees?

Angel. These five programs are offering college level associate degrees in reclamation technology. That means the students take roughly two years of college level training then receive an Associate Degree and if they want to enter the world of work right after that they can or they can transfer on to a four-year school and take two more years and get a Bachelor's Degree.

J. E. Winch (Canada). I'd like to know how many you had graduate and is there a demand in the United States for your graduates at this time?

Angel. So far—I really can't speak for the other schools—but Madisonville Community College of which I am a part, had employment of all of its graduates in the field. Since a lot of these schools are close together in Kentucky and the Appalachian region, I can see where the job market would very quickly become saturated, so we need to expand not only in our own coal or mining regions but into other nations as well. In fact at Madisonville Community College we have one man who's come down from the Northwest Territories of Canada solely to study reclamation technology at Madisonville and he's going back with his degree and I hope he'll take a couple of co-students along with him. So this is what our hopes are.

Terry Bradshaw (Liverpool, U.K.). I spent six weeks going around Australian mining operations. What horrified me is that in those mining sites that I saw (there were no less than 31 of them) was that there was some considerable success but there was also a lot of failure. The strict correlation was between the companies that had trained biologists who really knew what they were doing compared to companies which just got someone who was free—some sort of engineer who ran their environmental program. I said to them: you wouldn't think of having a biologist who wasn't very good in your drilling exploration program nor should you have an engineer who wasn't very good in your biology program. They've got to employ people with biological training. I hope that your sort of program can make that kind of impact.

Angel. The beauty of the reclamation technology schools is that they incorporate a multi-disciplinary training. Not only do they get the botany, the biology, the engineering, the forestry, soils, agriculture, and so on but they get, in many cases, field experience so when they get out and are ready to hire, they are highly qualified people and they can be hired at a cost that's not as expensive to the mining company as say a botanist or engineer is.

Robin Cuany (Colorado, USA). In our workshop on high altitude vegetation held this April, the director of the environmental protection technology training at Colorado Mountain College, in Leadville, described his course which is somewhat similar to what you've described as an associate degree, a two-year program combining biology, agronomy, and a little bit of engineering, and a little bit of mining technology.

Angel. I was aware of Leadville's program, but believed them to be only in the development stage.

Unidentified. Yes, they just graduated their first class this June.

95.
Dwindling Wildlife in the Changing Ecosystem of the Northwest Himalaya with Special Reference to Rare Birds and Mammals

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The mountains of India (Fig. 1) are peninsular and extrapeninsular. There is a great diversity in their formation, climate, flora and fauna. The Indian peninsular mountains include the Western Ghats, the Eastern Ghats, the Satpura, the Vindhya, and the Aravalli. But the Himalaya is an extrapeninsular mountain chain. The mighty Himalaya is stretched along the northern borders, cutting off the Indian plains from the high, cold plateau of Tibet and central Asia. The Himalayan ranges prevent the northward passage of the monsoons and also act as a barrier insulating the plains from the icy northern winter winds. The different Himalayan ranges (Mani, 1968) are grouped in the following two categories:

The Cis-Himalayan Ranges. These ranges lie south of the great Himalaya (the main range) and comprise the Shiwalik Range and the lesser Himalayan ranges. The Shiwalik Range separates the Himalaya from the Indogangetic plains and is the southernmost range of the Himalaya. The lesser Himalayan ranges extend between the main range (the great Himalaya) and the Shiwalik Range. They include the Nag Tibba, the Dhauladhar, the Pir Panjal, the North Kashmir, the Mahabharat, the Mussurie, and the Ratan Pir ranges (Fig. 2).

The Trans-Himalayan Ranges. These lie north of the main range and include the Zaskar, Ladakh, and Karakoram ranges.

Himalaya (Sanskrit: Him—snow, Alaya—abode), as the name signifies, remains snow-bound at its higher reaches practically throughout the year, but at the same time it provides excellent ecological and biogeographical divisions of several floral and faunal communities. The Himalayan ranges provide climates varying upwards from tropical through subtropical, warm temperate, cool temperate to sub-alpine-alpine, and arctic. The different climatic, altitudinal zones which determine the flora and fauna are as follows:

MOUNTAIN ZONES

Sub-zone 1. The lower hills between 900–1 000 m, covered with broad-leaved wet forests.

Sub-zone 2. The middle and upper mountain evergreen forests up to an elevation of about 2 000 m.

Sub-zone 3. Between 2 400–3 000 m, forests of Sclerophyll broadleaved plants, mainly *Quercus* and *Rhododendron*.

Sub-zone 4. Between 3 000–3 600 m is the *Betula* zone, which is followed upwards by the shrub zone. The distinctive shrubs found are *Abies spectabilis*, *Rhododendron campanulatum*, *R. anthopogon*, and *R. setosum*.

Sub-zone 5. Above this zone comes the permanent snow line or the arctic zone.

The altitudes for these zones differ considerably in the eastern and western Himalaya.

VALLEYS

In addition to the altitudinal zones on the Himalaya, there are some beautiful valleys among its different ranges. These valleys are the granaries of the hills, often differing in their ecological characters. The outer valleys among the Shiwalik and lesser

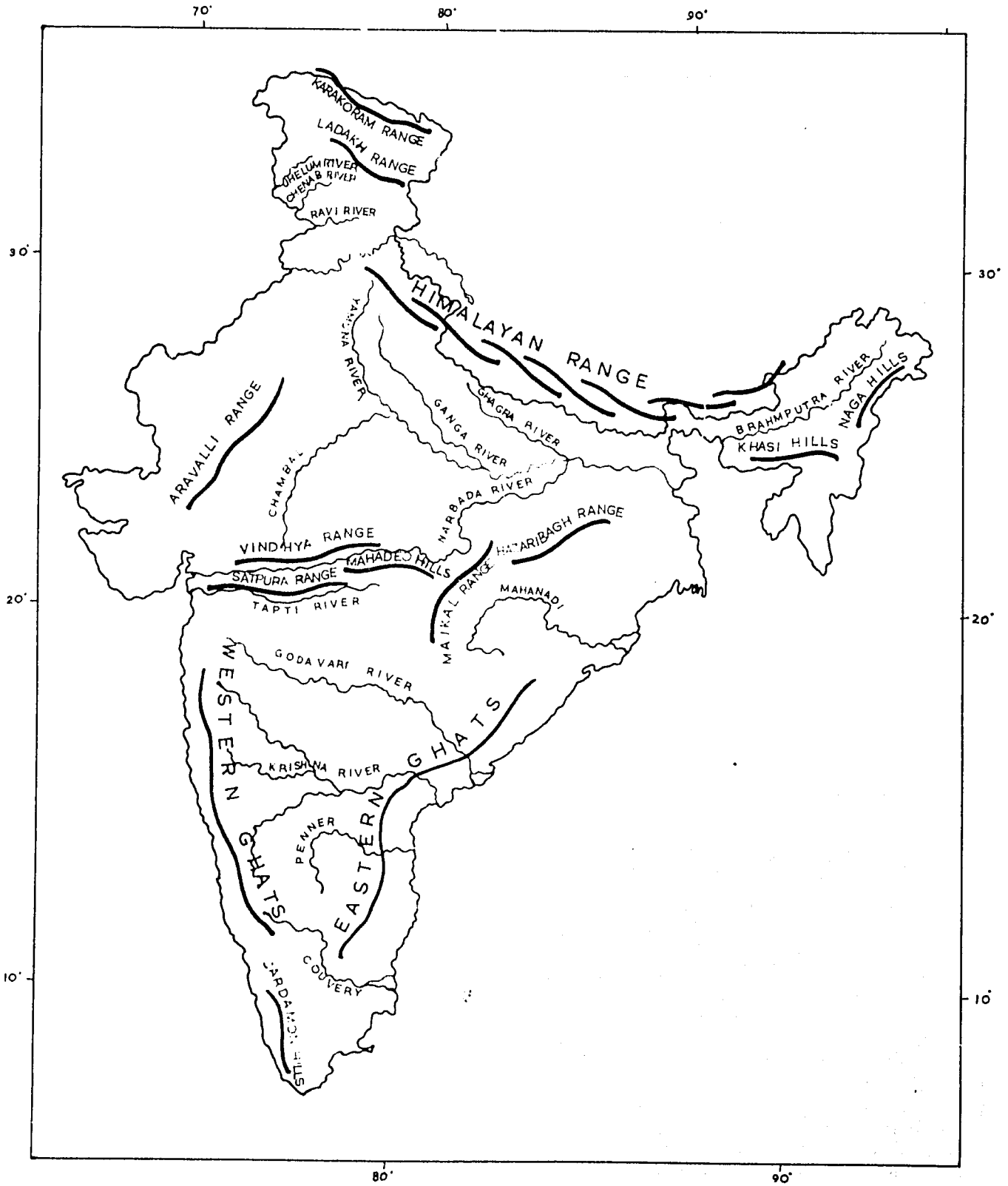

Figure 1. Positions of main mountains and the rivers of India.

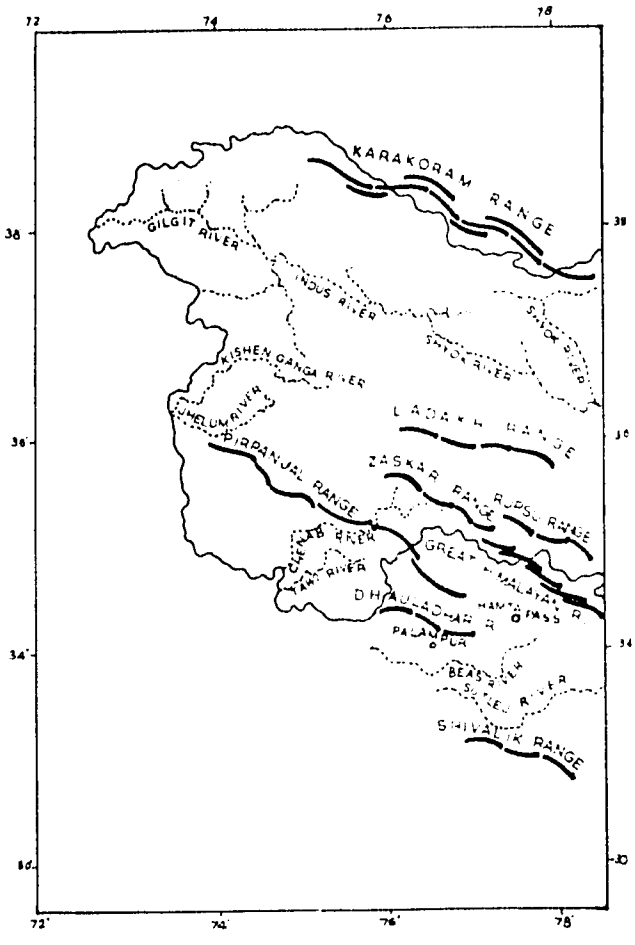

Figure 2. Enlarged view of the main mountain ranges in the northwest Himalaya.

Himalayan ranges provide a different set of agro-climatic conditions from those between the lesser Himalaya and the great Himalaya. The outer valleys in the northwest Himalaya include the Kangra valley between Shiwalik and Dhauladhar ranges; the Kulu valley between Dhauladhar and Pir Panjal ranges; the Kashmir valley among Pir Panjal ranges; and the Kalpa valley among Dhauladhar. These valleys produce good crops of wheat, maize, rice, and potatoes. On the slopes of these valleys are situated some of the famous orchards of apple, peach, pear, and cherry. These valleys have been developed for cultivation after removal of forests. The Lahaul valley, cold and dry, is an interior valley situated to the north of Pir Panjal range and south of the great Himalayan range. This valley remains snow-locked for about six months in a year. Barley, buckwheat, and potatoes are the major food crops grown there. However, other vegetables and wheat have recently been introduced. Kangra valley receives high rainfall (maximum 4437 mm/annum) as compared to Kulu valley (maximum 789 mm/annum) and Lahaul valley (maximum 435 mm/annum) as the western monsoons strike the mountains for the first time at Kangra and the eastern monsoons also exhaust themselves by the time they reach Kangra.

AQUATIC ZONE

Another ecological habitat which is a peculiarity of the Himalaya is due to the heavy snowfall during winter on its upper reaches and permanent snow and glaciers on the main Himalayan ranges. The huge snow accumulation constitutes an immense water reservoir of India. Most of its rivers are the consequent rivers thought to have developed after the mountains were formed. In the northwest Himalaya the rivers which need special mention are the Chandrabhaga (or Chenab), which flows just above Kishtwar. The Chandra and the Bhaga issue on opposite sides of the Bara Lacha pass. The Beas (Veas Vipasa) originates in the Pir Panjal Range at the Rohtang pass. River Solang arising from Solang glaciers is the major tributary of River Beas. The Sutlej (Satadru) (Misra, 1970) is an antecedent river thought to have existed before the formation of the Himalayas whose course is traceable to the western region of the Lake Manasarovara. It runs a little towards the southwest above Mount Kamet as well as Simla hills. These rivers at the higher elevations are devoid of any vegetation except for some mosses and algae which provide an inexhaustible source of food for the larvae of Dipterous families viz. Blepharoceridae, Deuterophlebiidae, Simuliidae, Chironomidae, Psychodidae, and Tipulidae (Kaul, 1970, 1971, and 1976). Ephemerida, Plecoptera, and Trichoptera are also abundant in the feeder glacial streams of these rivers (Kaul, 1970).

THE FLORA AND FAUNA

The Flora

Subtropical semi-desert types occur at the foot of the mountain. The flora is comprised of *Calotropis*, *Capparis decidua*, *C. spinosa*, *Ephedra*, *Pistacia*, *Euphorbia rovleana*, etc. (Mani, 1974).

Cymbopogon, *Enneapogon*, *Stipa*, and *Saccharum* species are dominant along with some of the members of chenopodiaceae and asteraceae. Woody elements include species of *Berberis*, *Colutea*, *Sophora*, *Rosa* etc. Conifers at 3000–3600 m include *Abies pindrow*, *A. spectabilis*, *Cedrus deodara*, *Picea smithiana*, and *Juniperus*. At elevations 3800–3900 one finds *Betula utilis* with *Abies*, *Juniperus*, *Pinus wallichiana* *Sorbus*, etc. Alpine zone herbs are *Aconitum*, *Aquilegia*, *Aster*, *Astragalus*, *Corydalis*, *Draba*, *Leontopodium*, *Potentillia*, *Primula*, *Saxifraga*, *Anemone*, *Saussurea*, *Thymus*, etc.

Subtropical forests with *Olea cuspidata, Dodonea viscosa, Punica granatum, Pinus roxburghii* occur at altitudes of 900–1 700 m.

The natural flora of Lahaul valley includes many species of *Astragalus, Oxytropis* with species of *Artemisia, Ephedra,* Hippophäe. *Arenaria* is common along Chandra River. Herbs such as *Eremurus, Arnabia, Cynoglossum, Eritrichium, Caltha Palustris, Pedicularis punctata, Iris* grow along the glacial streams. The dry slopes of Lahaul valley are covered with *Berberis jaeschkeana* and *Cousinia thomsonii.*

A survey of Himachal Pradesh, a hill state in the northwest Himalaya, reveals that there are many medicinal and aromatic plants which constitute the raw material for the phyto-chemical and essential oil industries. The following are a few such plants which form only a part of the still many more uninvestigated plants:

Name of Plant	Active Principle
Artemisia maritima (Compositae)	Santonin
Ephedra gerardiana (Ephedraceae)	Ephedrine
Dioscorea deltoidea (Dioscoreaceae)	Diosgenin
Heracleum candicans (Umbelliferae)	Xanthotoxin
Physochlaina praealta (Solanaceae)	Hyoscymine
Costus speciosus (Zingiberaceae)	Diosgenin

Name of Plant	Perfume/essential oil
Valeriana jatamansi (Valerianaceae)	Oil of Valerian
Saussurea lappa (Compositae)	Costus oil used in perfumery
Juniperus macropode (Cupressaceae)	Juniper-berry oil
Artemisia dracunculus (Compositae)	Oil of estragen
A. vestita (Compositae)	Aromatic essential oil
Tagetes minuta (Exotic, now naturalized) (Compositae)	Tagetone
Thymus sp. (Labiatae)	Thymol

Sufficient quantities of these raw materials are available and are collected from the wild. Only *Saussurea lappa* is grown as a regular crop in Lahaul. *Dioscorea deltoidea* is being tried for cultivation at Solan in the experimental farm of the department of forestry, Himachal Pradesh University. *Heracleum candicans* came into the limelight only recently. Xanthotoxin extracted from its rhizome is used in the treatment of leucoderma and psoriasis. It is used in the preparation of sun-tan lotions also. Since the natural stocks of those raw materials that are in great demand are likely to be depleted, they can be introduced as crops under the specific agro-climatic conditions. In this regard, *Dioscorea deltoidea, Heracleum candicans, Costus speciosus* deserve special mention.

The Fauna

The permanent abodes of animals at the highest altitude (6 800 m) in the world are found only in the Himalaya. At such an elevation Collembola, Diptera, and Acarina were discovered. One family of Dipera viz. Deuterophlebiidae is distributed at the permanent snow line where in addition are also found the members of the families Blepharoceridae, Chironomidae, Simuliidae, and Psychodidae. Ephemerida, Plecoptera, and Trichoptera are also common. Hymenopterous parasites belonging to Chalcidoidea and Ichuminoidea and other insect orders are well distributed.

The important wild vertebrate fauna of the Himalaya consists of some of the most beautiful birds and heavy mammals.

Avifauna of the Himalaya (Ali, 1949, 1969; Delacour, 1951) includes *Corvus macrorhynchos* Wagler and *Dendrocitta formosae* (tree pie) Swinhoe, in thick forests; *Nucifraga carvocatactes* (Himalayan nut cracker) Vigors; *Enicurus maculatus* (the spotted forktail) Vigors; *Megalaima virens* (Himalayan barbet) Swinhoe; *Apus melba* Linnaeus (the alpine swift); *Caprimulgus macrourus* Horsfield (the long-tailed night jar); *Glaucidium cuculoides* Vigors (the Himalayan barred owlet); *Columba leuconota* Vigors (snow pigeon); *Gennaeus hamiltoni* Griffith (the white crested Kaleej pheasant); *Ceriornis macrolophus* (Koklas); *Catreus wallichii* (cheer); *Lophophorus impejanus* (Monal); *Tragopan melanocephalus* (Fulgar); *Arborophila torqueora; Alectoris chukor; Scolopax rusticola* (woodcock); *Pavo cristatus* (peacock).

The mammalian fauna distributed on the Himalaya is composed of the following animals (Blanford, 1901; Gee, 1964; Kalia, 1974): *Muntiacas muntiak* (barking deer) subfamily Muntiacinae; *Cervus unicolar* (Sambar). The members of the family Bovidae, subfamily Bovinae, are *Bubalus bubalis* (Asiatic buffalo), *Bos indicus* (ox), *Bos frontalis* (gayal), and *Bos grunniens* (yak). The subfamily caprinae is represented by *Naemarhedus goral, Hemitragus jemlachieus* (Himalayan Tahr), *Capra ibex, Capra hiscus, Capra falconeri falconeri.* Carnivora form the complex of *Canis lupus* (Wolf), *Vulpes vulpes* (Red fox), *Ailurus falgens* (Red Panda), *Hyaena hyaena, Felis* species, *Neofelis nebulosa* (clouded leopard), and species of genus *Panthera. Sus cristatus* (wild pig) if found in the foot hills.

VANISHING FAUNA OF THE HIMALAYA

It is distressing to remark that some of the beautiful birds and mammals have not been sighted in recent years. The following spec' of birds were common only a few years ago (Ali 1960; Ripley, 1949 and 1952).

Rhodonessa caryophyllacea (pinkheaded duck), which was very common at the foot hills of the Himalaya, does not seem to have been seen after C. M. Inglis in 1935.

Ophrysia superciliosa (grey mountain quail). This species is related to the blood-pheasants in appearance, occurring in grasslands at elevations of 1 520–2 130 m. It is believed that it has not been seen since 1952. Even at that time the area in which it occurred was only 2% of the former size of its range.

The vanishing mammals are (Harper, 1948; Perry, 1964; Street, 1961):

Bos grunniens mutus (the wild yak). Lives in high and rugged snow-covered mountains and valleys at elevations of 3 300–4 500 m. This species is now restricted to inaccessible and remote areas.

Capra falconeri falconeri. This large, wild goat, with silky hair is a thick-coated and heavy animal, standing about 100 cm at the shoulder and has been extensively hunted by man. The magnificent horns of the male measure about 165 cm and are corkscrewed. The older males possess a long black beard and a grey mane. Only about fifty years ago it used to roam about in large herds along the streams and rivers in the Pir Panjal, but it is now confined to remote and inaccessible pockets of Pir Panjal, just about one-fifth of its former range of habitat.

Cervus elaphus hanglu. Another inhabitant of high ranges, similar in appearance to the European red deer, is becoming rare.

Moschus moschiferus moschiferus (musk-deer). An inhabitant of the forests of the Himalaya, around 2 500–3 800 m elevation, now occurs only in about one-fourth of its former range of habitat.

Panthera tigris tigris was very common only a few years ago in the foothills, but now, as a result of indiscriminate hunting for its precious hide, has become very rare.

Panthera unica (the snow leopard). An inhabitant of 2 000–4 000 m elevation is now very rare.

FACTORS DISTURBING THE ECOSYSTEM AND CORRECTIVE MEASURES

The phenomenon of dwindling or disappearance of wildlife is directly related to man and his activities. The ever-increasing demand for food, clothes, and shelter of ever-growing human population, coupled with man's insatiable lust for supremacy over land, water, and air and his unquenchable quest for discoveries and inventions to achieve his goals without proper appreciation of side and after effects of his actions, could only have led to the present geo-biological imbalances and maladjustments. Some of the factors that have contributed to the present situation include:

Deforestation. In order to bring more land under cultivation of short duration food and fiber crops the forests have borne the major brunt, resulting in irreversible adverse effects on the existing flora and fauna. In the process, some of the species disappeared, some were driven to inhospitable environments, while others got confined to smaller niches.

Cultivation of Hill Slopes. Advance of cultivation from valleys and flat grounds to the slopes denuding the soil surface and exposing it to erosion has brought about major upsets in the established eco-systems.

Communication. The need to expand and improve the roads and railways for a variety of justifiable economic and political reasons necessitating cutting of land, tunnelling of hills, blasting of rocks has had considerable adverse effect on the wildlife of the hills and mountains.

Irrigation and Hydro-electric Projects. Another very important factor disturbing the existing eco-systems is the ponding of runoff water, damming of rivers, diversion of water from one river to the other for the purpose of irrigation or generation of electricity, again necessitated by human needs and modernization of life.

Industrialization and Urbanization. The spread of the towns and the cities to the surrounding villages has resulted in the destruction of the natural forests and the wildlife in addition to creating a polluted atmosphere.

Military Operations and Exercises. Such operations for the country's defense along the elevated borders have disturbed the quiet habitats of several species of wildlife at high altitudes. The firing practices and the resultant echoes scare the wildlife and drive them to less habitable environments where their breeding efficiency is bound to decline.

Hunting and Poaching. Another important, and in some cases the only, cause of the vanishing of wildlife. Reckless and indiscriminate hunting of wild animals for food and decorative plumage and skin has caused immense harm to the wildlife of which the majestic tigers and colorful *Lophophorus* (Monal) of India are good examples.

It is thus evident that the existence and perpetuation of wildlife, particularly at the high elevations, has reached a precarious stage. The need for preserving the natural habitats of most of the rare and precious wildlife, the variety and number of which is fast dwindling under the force of the factors enumerated above, can hardly be overemphasized. Concerted efforts are required to contain the operation of these forces before it is too late.

The situation calls for positive action to preserve and rehabilitate the vanishing wildlife. To declare some of the watersheds where the rare wildlife is still in existence, though in declining number, as the sanctuaries where the human encroachment in any manner, much less hunting or poaching, is strictly forbidden, would be a step in the right direction. Wherever possible the non-existing species in that sanctuary may be introduced. Happily, a number of such watersheds are still available where the wildlife can be perpetuated and flourish in nature's own way.

To supplement nature's role, artificial propagation and rearing of precious wildlife should be undertaken by the institutions located in or near the wildlife habitats, with substantial financial support from the government, semi-government, or other organizations or societies interested in this task. Though there is evidence of awareness on the part of the government and certain other societies of the need for the preservation of wildlife, it leaves much to be desired in so far as the practical impact is concerned.

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DISCUSSION

R. Brougham (New Zealand). Is it a fact that in your country, as I understand it is in most countries, that if anything positive is to be done to protect some of these species it has to be done at a national level?

Kalia. It's true all over the world. There is a political rule where there is public will. The public opinion, of course, is not based on realities but we are now in a state where we must take recourse to the legislation makers. Even the public are not aware of their own needs and not aware of their own interests. Those interests have got to be told to them and for that purpose we think the legislation makers are the only ones.

96.
Ecology of Borrow Pits

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Surface mining is the process of recovering desired minerals after the removal of topsoil. Methods of this kind, including strip mining, auger mining, quarrying and dredge mining, are used throughout the United States for the extraction of coal, gold, uranium, and other mineral resources. In Rhode Island, sand, gravel, and stone are the only materials for which areas are surface mined. Sand and gravel extraction is an important industry which supplies the raw materials needed for building and highway construction. The amount of land being utilized for sand and gravel recovery has increased in direct proportion to the increase in construction. A remote sensing land-use study, conducted in Rhode Island by MacConnell (1974), concluded that 1 288 ha were utilized for sand and gravel extraction.

In the past, most of the surface mined areas were concentrated around urban centers and highway construction sites; however, as these areas have become worked-out and abandoned, new operations have opened in rural areas. Some abandoned gravel pits have been utilized as sanitary land fills and construction sites but the majority remain as bare areas or ephemeral ponds if subsurface water levels are high. Preliminary investigation suggests that many abandoned gravel pits support sufficient terrestrial and/or aquatic vegetation to provide wildlife habitat and a unique environment (in a forested area) that has potential for outdoor recreation.

Rhode Island's land resources are limited and the distribution of gravel pits is such that it would appear that important uses could be made of their "open space" qualities. Nature study areas, swimming areas, and wildlife production areas are some of the distinct possibilities. While the location of most Rhode Island gravel pits is known (Moultrop, 1964), the basis for their recreation potential (vegetation and wildlife) is not.

The primary objectives of this study were to determine the plant and animal communities of selected abandoned Rhode Island gravel pits.

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METHODS

Three abandoned borrow pits (Sites 1, 2, and 3) in southern Rhode Island (ca 71°30′ longitude; 41°27′ N latitude) were selected for study from an inventory of Rhode Island pits compiled by Moultrop (1964). The study pits showed no evidence of reexcavation following the initial abandonment and each pit differed in age since abandonment. These criteria allowed for an analysis of plant successional patterns. The age of gravel pit sites since abandonment was determined primarily by comparison of aerial photographs taken in 1939, 1951, 1962, and 1972.

Vegetation Analysis

Three methods were utilized to determine the following vegetation characteristics: (1) the species and frequency of occurrence of understory plants, (2) the species and features of trees in the overstory, and (3) the percentage of various cover types comprising the ground layers.

Understory composition was determined by employing the point-intercept method on line transects across the long axis of the pit. All species intercepted by a point dropped at each 15 cm designation in a plane along the transect from ground level to a height of 1 m were recorded. "Bare ground" or "leaf litter" was registered when no plants were present at the sampling site. Frequency of occurrence was calculated by dividing the total number of times a species was intercepted by the total number of points sampled.

Overstory vegetation was sampled by using belt transects 2 m wide that traverse the long axis of a study pit. Stem counts were made of all tree species below 1 m in height as an indication of seedling and sprout regeneration. Trees higher than 1 m were measured for total height and dbh (diameter measured at 1.37 m above ground). Increment cores were taken from stems of the larger diameters so as to determine tree ages.

Low ground cover was sampled for type and area occupied. Ground cover categories included bare ground, leaf litter, moss-lichen, grasses, broad-leaved herbaceous and woody plants. At each study pit, 100 randomly located 1 m square plots were photographed in color from a point directly over the center

of each plot. Cover types were identified and ground areas covered by each were calculated.

Data on density and crown closure of vegetation adjacent to pits were obtained from land use maps published by Kupa and Whitman (1972). The nomenclature used for plants is according to Fernald (1950).

Physical Site Factors

Soil samples were collected from all ground-cover types of the study pits so as to assess the edaphic influence in the revegetation process. Samples were taken from ground surface to a maximum depth of 15 cm and were analyzed for pH, texture, and percent organic matter.

Ground water levels were monitored by inserting a 2.7 m long, 10 cm diameter (Polyvinylchloride) tube into the substrate.

Data on materials initially excavated from pits were compiled from Moultrop (1964).

Wildlife Use Analysis

Bird observation stations were established at each pit and were used for ten minutes in the early morning or evening of observation days. Species of birds using the pit or adjacent areas were recorded and special note was taken of breeding activity within the pit.

Occurrence of mammals was determined primarily through trapping procedures. Larger animals such as cottontail rabbits were live-trapped by standard procedures for a two-year period. Sex, age, and various body measurements were obtained from captured animals. Each was ear tagged so as to facilitate identification of recaptured individuals.

Small mammal populations were studied by trapping and home range delineation. Snap trapping was conducted in three habitat types: wooded, closed canopy, grass-shrub and bare ground grasses. Adjacent areas were trapped less intensively than the pits.

In addition to snap trapping, live trapping was done in a standard manner on Site 2 so as to be able to identify recaptured individuals. Capture and recapture locations were mapped for each individual and home ranges were calculated using the inclusive boundary strip method described by Blair (1940). Nomenclature for vertebrate animals is from the A.O.U. checklist (1957) and Supplement (1973) for birds and Blair *et al.* (1957) for mammals.

RESULTS AND DISCUSSION

Vegetation

A total of 111 species of vascular plants was recorded at the three study areas. Among the species sampled were 67 herbs, 23 trees, 15 shrubs, and 6 vines.

Relative frequencies were computed from data obtained through the point-intercept method. Percentages were tabulated to compare plant life forms and bare ground in both sections of Site 1, Site 2, and Site 3 (Table 1). In comparing the results for the three study areas the sequence of revegetation could not be drawn to describe, in general, successional patterns in abandoned pits. The oldest pit was not necessarily the one which had the most advanced seral stage. Differences in the physical site conditions of each area were responsible for this.

Successional patterns can only be analyzed at Site 1 where two sections of known different age exist. The old section is about 40 years old and the new section 25–30 years old. The site conditions, except for the time of disturbance, are basically similar; therefore, conclusions can be drawn on the rate and pattern of development at this study site. The results at Site 2 (minimum age, 35 years) and Site 3 (about 10 years) must be considered separately with respect to site conditions. Conclusions can then be drawn concerning the factors which may accelerate or retard successional advance in abandoned gravel pits through the comparison of these three study sites.

At Site 1 it appears that initial plant invasion is by mosses, lichens, and grasses. *Andropogon scoparius* Michx. is the dominant form of herbaceous vegetation and accounts for 21.7% of the plants sampled of this life form in the new section. Other herbaceous plants in the new section included *Festuca ovina* L. (16.2%), *Solidago odora* Ait. (1.3%), and *Solidago tenuifolia* Pursh (1.2%). In the old

TABLE 1. Relative frequency of plant life forms and bare ground on three excavated gravel sites, based on point intercept sampling

Form Category	Site 1 Old	Site 1 New	Site 2	Site 3
Bare ground	4.9	8.5	10.3	44.2
Pioneer Ground Cover				
Lichens	4.6	10.3	21.2	1.5
Mosses	9.1	20.4	28.9	3.3
Total	13.7	30.7	50.1	3.8
Herbaceous				
Grasses	27.4	35.4	14.6	8.6
Broad-leaved	13.6	5.8	7.3	22.6
Total	41.0	41.2	21.9	31.2
Woody				
Shrubs	32.3	15.3	4.4	1.2
Trees	8.1	4.3	13.3	19.6
Total	40.4	19.6	17.7	20.8

section, the frequency of occurrence of *Andropogon* decreases (5.9%) as the frequency rises for *Festuca* (19.2%). *Festuca* is found primarily on the steep banks in contrast to *Andropogon* which grows on the floor of the pits. The number of herbaceous plants increased in the old section with the addition of *Solidago juncea* Ait. (2.5%), *Solidago graminifolia* (L.) Salisb. (2.4%), *Rumex acetosella* L. (1.2%), *Solidago rugosa* Ait. (1.1%), and *Poa compressa* L. (1.1%).

The establishment of woody vegetation appears to occur rapidly in abandoned gravel pits. Twelve *Robinia Pseudo-Acacia* L stems, in the new section of Site 1, were analyzed for age. Results showed that *Robinia* became established on the site approximately ten years after abandonment. It appears that woody vegetation closely follows the establishment of initial ground cover and herbaceous communities. Other woody plants which were recorded in the new section include *Myrica pennsylvanica* Loisel (5.6%), *Rhus radicans* L. (3.9%), *Lonicera japonica* Thumb. (2.7%), *Rubus hispidis* L. (2.5%), and *Prunus serotina* Ehrh. (1.0%). In the old section, additional woody plants include *Celastrus scandens* L. (1.9%), *Gaylussacia baccata* (Wang) K. Koch (1.2%), *Quercus alba* L. (1.1%), *Acer rubrum* L. (1.1%), and *Populus tremuloides* Michx. (1.1%).

The first invaders at Site 1 are those which have wind-dispersed seeds, as is the case with *Andropogon*. The dominant tree species in the new section, Robinia and Prunus, probably owe their occurrence to seed dispersal by animals.

The ultimate development of a mixed Quercus forest was apparent in the older section of Site 1. Belt transect data showed a significant increase in the more mesic trees including *Quercus coccinea* Muenchh., *Quercus alba* L., *Quercus velutina* Lam., *Fraxinus americana* L., and *Cornus florida* L. Initially, *Robinia* was the invading tree species on the site. Moreover, it appears that this species alters the xeric environment of the open gravel pit to a more mesic habitat. The nitrogen-fixing ability of this species (Ashby, 1964) improves soil fertility which results in increased species diversity. Also, the formation of the *Robinia* community provides suitable habitat for small forest mammals which aid in the dispersion of *Quercus* through burying of acorns.

The continued development of forest vegetation in the old section will involve the disappearance of *Robinia*, due to its shade-intolerance, and an increase in the density and cover of a mixed *Quercus* community.

Although the gravel pit at Site 2 is older than the new section of Site 1 by approximately 5-10 years, the vegetation at Site 2 is not as well-developed. A higher percentage of bare ground and moss lichen is present at Site 2.

The physical site factor which varied the most between the two sites was the depth of ground water. At Site 1, the ground water level was below 2.5 m, whereas at Site 2 it was within 0.5 m of the surface, and within a few cm of the surface in depression. Ephemeral pools of water occasionally formed in these depressions during wet periods. This annual flooding inhibits the development of upland vegetation while the disappearance of this water in drier periods prevents invasion by wetland species. In areas which are not flooded, but feature water near ground surface, large areas of bare ground occur. The establishment of most vegetation is mechanically retarded by the annual freezing and thawing of the soil.

At Site 3 the distribution of vegetation was limited to areas adjacent to a small (1.8 m wide) stream which bisects the site. *Salix Bebbiana* Sarg. formed the dominant vegetative cover (30% of all plants sampled) at Site 3. The presence of permanent surface water has allowed a greater species diversity of wetland plants. The most common species include *Impatiens capensis* Meerb, *Lycopus rubellus* Moench, *Juncus effusus* L., *Juncus Greenei* Oakes and Tuckerm., *Phragmites communis* Trin., *Glyceria striata* (Lam.) Hitchc., and *Carex pennsylvanica* Lam.

The topography of the gravel pit has limited the development of vegetation in other areas of Site 3. The banks on both sides of the pit were sparsely vegetated due to the coarseness of the substrate and degree of slope which forms an unstable and droughty medium for plant establishment.

Wildlife

A total of 42 species of birds was recorded as utilizing the three gravel pit study areas (Table 2). Many of the birds are those classified by Johnston (1947) and Johnston and Odum (1956) as forest-edge species. These are defined by Johnston (1947) as "those species which are confined to the border of forest or which use both the forest and surrounding field in their activities." The forest edge is considered to be a distinct community which develops in the course of succession from field communities to forest.

Gravel pit sites provide two types of forest-edge habitat. First, the removal of vegetation, in the creation of gravel pits, forms two distinct communities: the open pit and the adjacent forest. Secondly, as vegetation develops on abandoned gravel pits, shrub islands form which, in some cases, are completely surrounded by open areas. A mixture of this kind provides the distinct habitat differences utilized by forest-edge birds. The eventual reforestation of the gravel pits will probably result in the replacement of forest-edge species with typical forest species. *Sylvilagus floridanus* and the *Didelphis marsupialis*

TABLE 2. Species and status of birds recorded at the three study areas (a = abundant; c = common; u = uncommon; o = occasional)

Species	Site 1 New	Site 1 Old	Site 2	Site 3
Great Blue Heron (*Ardea herodias* L.)	—	—	—	o
Black Duck (*Anas rubripes* Brewster)	—	—	—	o
Red-tailed Hawk (*Buteo jamaicensis* Gmelin)	—	—	—	o
Bobwhite (*Colinus virginiana* L.)	—	—	u	—
Spotted Sandpiper (*Actitus macularia* L.)	—	—	—	o
Herring Gull (*Larus argentatus* Pontoppidon)	—	—	—	a
Chimney Swift (*Chaetura pelagica* L.)	o	—	—	—
Common Flicker (*Colaptes auratus* L.)	u	—	—	—
Eastern Kingbird (*Tyrannus tyrannus* L.)	—	—	o	—
Great Crested Flycatcher (*Myiarchus grinitus* L.)	u	—	o	—
Tree Swallow (*Iridoprocne bicolor* Viellot)	u	u	—	—
Barn Swallow (*Hirundo rustica* L.)	u	—	o	—
Blue Jay (*Cyanocitta cristata* L.)	c	c	u	u
Common Crow (*Corvus brachyrhychos* Brehm)	o	—	—	—
Black-capped Chickadee (*Parus atricapillus* L.)	c	u	c	—
Mockingbird (*Mimus polyglottos* L.)	o	o	u	u
Gray Catbird (*Dumetella carolinensis* L.)	c	c[a]	c[a]	c[a]
Brown Thrasher (*Toxostoma rufum* L.)	—	—	o	—
American Robin (*Turdus migratorius* L.)	c	c	c	c[a]
Wood thrush (*Hylocichla mustelina* Gmelin)	o	—	—	u[a]
Starling (*Sturnus vulgaris* L.)	o	u	o	—
Black-and-White Warbler (*Mniotilta varia* L.)	—	—	o	—
Yellow Warbler (*Dendroica petechia* L.)	u	—	—	c[a]
Red-winged Blackbird (*Agelaius phoeniceus* L.)	—	—	—	c[a]
Northern Oriole (*Icterus spurius* L.)	c	o	—	—
Common Grackle (*Quiscalus quiscula* L.)	o	o	—	—
Brown-headed Cowbird (*Molothrus ater* Boddaert)	o	o	—	—
Cardinal (*Cardinalis cardinalis* L.)	—	c[a]	u	—
Rose-breasted Grosbeak (*Pheucticus ludovicianus* L.)	o	—	—	—
Indigo Bunting (*Passerina cyanea* L.)	—	—	o	—
American Goldfinch (*Spinus tristis* L.)	u	—	—	—
Rufous-sided Towhee (*Pipilo erythropthalmus* L.)	c	—	c[a]	c
Chipping Sparrow (*Spizella passerina* Bechstein)	—	—	u	—
Field Sparrow (*Spizella pusilla* Wilson)	u	—	—	—
White-throated Sparrow (*Zonotrichia albicollis* Gmelin)	o	—	—	—
Song Sparrow (*Melospiza melodia* Wilson)	c	c[a]	c[a]	c[a]
Mourning Dove (*Zenaida macroura* L.)	u	—	c	u
Killdeer (*Charadrius vociferus* L.)	—	—	—	o

[a]Indicates evidence located for nesting within the gravel pit.

L. were the only species of large mammals live-trapped in the gravel pits. *Sciurus carolinensis* Gmelin, *Tamias striatus* L., and *Marmota monax* L. were also observed in the pits.

Eight white-footed mice, eight *Blarina brevicauda* Say, and one *Microtus pennsylvanicus* Ord were captured during the trapping survey on Site 1. The majority of captures for all species were recorded from the closed canopy forested areas within the gravel pit rather than from the open, herbaceous communities.

At Site 2, where a home range survey was conducted, 44 small mammals were captured. The dominant species, and the only species which was captured within the gravel pit, was the white-footed mouse. Eight individual mice were selected for calculating home range on the criterion that they were captured more than three times. Juvenile mice were the only individuals captured within the gravel pit. Since suitable habitat for white-footed mice consists primarily of forest areas (Getz 1961), it would appear that the occurrence of mice in the open pit is due to juveniles dispersing from a population of the adjacent forest habitat.

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97.

Reclamation and Management of Surface Mines for Game and Non-Game Birds

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In 1975, 4750 ha of hill land were disturbed and reclaimed in West Virginia (W.Va. Dept. Natural Resources, 1976). As of October, 1971, contour surface mines disturbed nearly 100000 ha of hill land in West Virginia (Stanford Report, 1972). In recent years, the amount of land reclaimed in West Virginia has increased. In 1971, surface mining in West Virginia disturbed 6320 ha, while 8148 ha were reclaimed (B. Lusk, pers. comm.). About 43600 ha of surface mined land still require reclamation in West Virginia (Stanford Report, 1972).

Methods for revegetation have changed in recent years from the use of trees to a stabilization process of planting annuals, grasses, and legumes. First-year growth of annual grains on these sites is usually quite dense (Fig. 1); grasses and legumes remain but usually decrease in density from years 2 to 5 (Fig. 2). Such reclamation in general converts forested land and some tillable land to grasslands. It also alters the fauna present in the area.

Revegetation as presently done slows the rate of succession and 50-100 years may be required for the vegetation to return to a pre-mined state. Rate of succession might be increased by some selective planting of trees and shrubs at the time of original seeding or as part of a secondary reclamation plan 5-10 years after mining. This would allow stabilization and increase plant diversity.

The mining operation also has changed in the past 20 years. Previously, mining operations were relatively small, little land was disturbed, the surface mine bench was narrow and new edges were created in forests having a diversity of cover types beneficial to wildlife (Riley, 1954). Today, larger earth-moving equipment creates vast areas of mined land, and as with most grassland, diversity is low. This is evidenced by comparing the higher breeding bird counts from older surface mines with the lower counts made on more recently reclaimed mines (Brewer, 1958; Karr, 1968; Terrel and French, 1975).

VARIABLES

Various factors affect the species and number of birds found on reclaimed surface mines. These include age of mines (which determines successional changes and indicates the existing law that governed reclamation at the time of mining), size of the site, vegetation on the site, and conditions of the soil, slope, aspect, climate, and surrounding habitat.

RECLAIMING FOR GAME BIRDS

Basically two types of reclaimed mines are found in northern West Virginia: sites reclaimed 10-20 years ago consisting of rather dense tree stands and some understory shrubs or grasses (although acid conditions on some of these older sites preclude

Figure 1. First growing season of a reclaimed surface mine seeded to a mix of annual grains, grasses and legumes. This site was mined twice; the second operation removed the highwall left after the first operation.

Figure 2. Reclaimed surface mine approximately five years after seeding to mixed annuals, grasses and legumes. Note bare patches of soil and taller lespedeza growing in lower right.

growth of any vegetation), and grassland sites. Many older sites are being stripped again and reclaimed to grasses (Fig. 1); and surface mines today are reclaimed as grasslands. Therefore, we shall limit our discussion to these sites. Our comments are based on observations made over the past four years of research.

Present reclamation procedures appear to favor agricultural species such as mourning doves and bobwhite quail since these species are abundant in agricultural areas. There is potential, however, for woodcock, ruffed grouse, and wild turkey when small grass clearings are created in a large forested area.

Mourning Dove

The most common American game bird, the mourning dove, nests in every state. It is abundant in hill country, especially along major rivers with mixed forests and farmlands. Doves nest on the ground or in shrubs and trees, commonly using conifers such as blue spruce (*Picea pungens*) and white pine (*Pinus strobus*) (Hanson and Kossack, 1963). Common foods are corn, wheat, various foxtails and millets (*Setaria sp.*), common ragweed (*Ambrosia artemisifolia*), and various noxious weeds and grasses.

Doves are known to breed on old surface mines (20–50 years old), where vegetation is diverse (Brewer, 1958; Karr, 1968). Terrel and French (1975) noted doves on recently reclaimed surface mines in Alabama, and we also observed high dove populations on first-year reclaimed sites, especially during fall migration. Such sites are often seeded to annual grains (e.g., wheat, rye, oats, buckwheat) and mixed grasses, and birds apparently were feeding on these grains.

Surface mines seeded to grasses could be made more attractive to doves if we did the following:

1. Seed annuals each year. This usually is done the first year in a mixture with grasses and legumes. Then, during the second growing season, the grasses and legumes take over and provide a stabilization cover crop. When seeding annuals after the first year, an area should be selected on the mined site with the poorest grass cover, to avoid competition.
2. Disc forest edges and hydroseed mixed shrubs. This also may encourage volunteer weed species.
3. Plant pines in clumps of 6–8 per ha, or rows every 80–90 meters (Davis, 1973; Vogel, 1973; Plass, 1974).
4. Check soil conditions over the years. As acid decreases through leaching, plant diversity can be increased by seeding millets and various legumes.

Remember that these and subsequent recommendations are not made from an economic viewpoint, but rather what might be best for wildlife. For example, hydroseeding most probably will benefit wildlife, but it could cost as much as $1000/ha.

Bobwhite Quail

The bobwhite quail is another common bird of the East. Adequate winter cover is a problem especially in the northern part of its range (which includes West Virginia), and winter mortality is apparently a limiting factor (Rosene, 1969).

Quail require well-drained and fertile soils with slope conducive to runoff but not erosion. Soil texture should be sandy or loamy and soil fertility must be high enough to maintain a good growth of weeds. Land with a mixture of uses (i.e., forest, cultivated, grazed, low shrubs) is best (Rosene, 1969). In Tennessee (Cady, 1944), Kentucky (Barbour, 1951), Virginia (Baldwin and Handley, 1946), and Indiana (Reeves, 1954) common foods of quail included seeds of lespedezas (*Lespedeza spp.*), ragweed, beggarweeds (*Desmodium spp.*), soybeans (*Glycine max*), corn and partridge pea (*Chamaecrista fasciculata*).

There is little literature on quail on surface mines, although Terrel and French (1975) noted their occurrence on a 15-year-old unreclaimed mine in Alabama. Much of the prime quail habitat lies south of major coal areas, but there is ample overlap and some things might be done to improve surface mine sites for quail. Recommendations 1, 2, and 4 (above) for doves would apply to quail. Soil acidity and texture on mines do not favor the vegetation needed by quail and doves. Fertilizers used each year may promote volunteer weeds. Creating "edge-effect" on the mine is important for wildlife (Research Committee on Coal Mine Spoil Revegetation in Pennsylvania, 1971). The lespedezas, a known quail food, grow well on acid soils (Vogel and Berg, 1968) and should be planted to help create edges (Fig. 2).

Woodcock

Although aspen (*Populus spp.*) and alder (*Alnus spp.*) are common to woodcock habitat (Dale, 1963) and do well on surface mined land, there is little potential for woodcock on mined hills. Soil texture and acidity on surface mines minimize the occurrence of earthworms, the major food of woodcock (Sheldon, 1971).

Ruffed Grouse

Ruffed grouse are common forest species in most of the northern United States. As with doves and quail, edge and scrubby early forest succession are very important for grouse. Abandoned farms in woodlands provide food and cover.

Grouse chicks consume insects until 5–6 weeks of age then switch to vegetation (R. Kimmel, pers. comm.). Common foods of adults are aspen buds, grape (*Vitis spp.*), greenbrier (*Smilax spp.*), acorns (*Quercus spp.*), cherry (*Prunus spp.*), cinquefoil (*Potentilla spp.*), clover (*Trifolium spp.*), and Christmas fern (*Polystichium acrostichoides*).

Many surface mines reclaimed in the 1950's (Fig. 3) provide good grouse brood range (R. Decker, pers. comm.). These mines have small clearings with low herbaceous ground cover, scattered trees and shrubs, and a sparse overstory. For unexplained reasons adults are also found at the base of spoil banks of

Figure 3. Site reclaimed in mid-1950's with good herbaceous and volunteer growth. Size of disturbed area is much smaller than that of today's mines.

these older mines in significantly high numbers (Arnold and Samuel, 1973). Grassland mines usually are too extensive in size to provide grouse habitat, and edge needs to be created. Recommendation 2 from above should be of help. Also, planting alder and aspen (although availability of seed is a problem) in rows or clumps of 3–4 ha should benefit grouse. Mature autumn olive (*Elaeagnus umbellata*) or black locust (*Robinia pseudoacacia*) both grow well on acid soils and may be of benefit to grouse.

Wild Turkeys

The eastern wild turkey is a forest-inhabiting species, but much has been written about its use of clearings (Bailey and Rinell, 1967). Small, managed clearings planted to grasses, legumes, and grains provide "types of food not found in forests" (Bailey and Rinell, 1967). These clearings also provide insects for young birds and dusting areas. High grasses found in clearings that are mowed only once every three years appear best for wild turkeys (W. Healy, pers. comm.). Again, all four recommendations for doves apply for turkeys.

RECLAIMING MINE SITES FOR NON-GAME BIRDS

Approximately 1,780 bird species of 97 families live and breed in North America, the overwhelming majority of which may be considered "non-game." We can ask two questions concerning non-game species and surface mine reclamation: First, why worry about non-game birds? Second, if we do worry about them, which species are important and how can we manage for them? The first question may be answered directly. Non-game birds are important ecologically, recreationally, and economically. Much of our present theory in ecology had its beginning with field studies on non-game birds (e.g., Sibley,

1950; MacArthur, 1954; Orians and Horn, 1969; and Emlen, 1972). No serious ecologist would doubt the importance of non-game birds to the ecosystem, but birds also have furthered our progress in other fields of science (Evenden, 1975). From a recreational standpoint it is impossible to estimate accurately the number of people who "watch birds." One estimate in 1972 placed the number of birdwatchers at over 14 million (Payne and DeGraaf, 1975). Interest in birds has increased dramatically in recent years; membership in the National Audubon Society has grown from 41 000 in 1963 to 321 000 in 1975 (Payne and DeGraaf, 1975). One paper reports that serious birdwatchers may equal hunters in stamina and may exceed them in knowledge of the out-of-doors (Payne and DeGraaf, 1975). Economically, non-game birds have received little national attention. However, in 1974, the American public spent more than an estimated $500 million enjoying non-game birds (Payne and DeGraaf, 1975), considerably more than the $300 million spend on game-bird hunting. This is an estimate based on direct expenditure and does not include the cost of such items as travel, clothing, and field expenses.

Answers to the second question are less obvious. How do we know which species are important to an ecosystem? The environmental purists may say "all of them," and this may be true. But if all of the component species of an ecosystem are important, then how can they all be returned to an impacted area such as a surface mine? The answer is simple: return the area to its original state. However, this may not be possible, and certainly not during the lifetimes of those who begin the reclamation procedures.

One over-riding problem with creating areas suitable for non-game birds is that knowledge about the specifics of avian habitat selection is lacking (Verner, 1975). We know which birds live in each general habitat type, but quantifying the relationships so that specific reclamation models can be constructed has not been achieved. Further, it has been established that habitat relations are important to birds more often than food dimensions, which are important more often than temporal dimensions (Schoener, 1974). Therefore, quantitative studies of birds and their respective habitats seems, at least, a reasonable first approach to the management of reclaimed surface mines. Until our data base on avian habitat use is increased, reclamation must continue. So the question remains: what to do now?

In temperate North America it has long been established that increased vegetational diversity leads to increased avial diversity (MacArthur and MacArthur 1961; Karr and Roth, 1971). Therefore, until the needed data are accumulated, it would appear that the goal of surface mine reclamation ought to be the same for non-game as it is for game birds: to increase vegetation diversity while still trying to retain and upgrade the soil.

The apparent goal of surface mine reclamation in West Virginia is to stabilize the topsoil as soon as possible. According to the 1971 surface mine reclamation law of West Virginia, the operator must have at least 80% vegetation cover after the first two growing seasons, spring and fall being two growing seasons. Therefore, most operators regrade and hydroseed the site, leaving behind an essentially uniform grassland, not unlike the Great Plains of North America. Obviously, the bird communities are drastically changed. Our research indicates that what was once a mixed deciduous forest supporting 45–50 non-game bird species becomes a grassland supporting 3–8 non-game species.

Associated with these grasslands are several species of sparrow which, prior to this form of reclamation, were not abundant in West Virginia. These species, including the grasshopper sparrow (*Ammodramus savannarum*), the savannah sparrow (*Passerculus sandwichensis*), and the vesper sparrow (*Pooecetes gramineus*), appear to have benefited from surface mine reclamation. They nest on surface mines where there is not 100% vegetation cover (Fig. 2). However, as the areas mature (i.e., 8–10 years after seeding) many sites have grass so dense and litter so deep that these sparrows will not nest (Fig. 4). Further, natural succession appears to be drastically slowed, since "pioneers" cannot get through the litter. Therefore, management of the grasslands seems needed. Several techniques commonly used by range managers, such as grazing or fire, undoubtedly would increase avian utilization and the rate of natural succession on reclaimed surface mines.

Figure 4. A site reclaimed in 1966. Ground vegetation increased from years 5 to 7 but has decreased over last three years. Scattered black locust occur on the bench and autumn olive along the highwall (top and bottom).

Minor changes in the vegetation structure can increase the species diversity of the grass-covered areas. Plantings of the shrub autumn olive provide nesting sites for a variety of birds, including song sparrows (*Melospiza melodea*), indigo buntings (*Passerina cyanea*), brown thrashers (*Toxostoma rufum*), gray catbirds (*Dumetella carolinensis*), yellow-breasted chats (*Icteria virens*), and ruby-throated hummingbirds (*Archilochus colubris*). During the fall and winter, shrubs such as autumn olive provide berries for many bird species, especially cedar waxwings (*Bombycilla cedrorum*), white-throated sparrows (*Zonotrichia albicollis*), and robins (*Turdus migratorius*). It may not always be economically feasible to make special plantings of shrubs, but their seeds could be included with the grasses when the areas are hydroseeded, with little increase in expense. The resulting reclaimed areas would be vegetationally more diverse and esthetically more pleasing, and the resulting avifauna would be far richer. In some areas black locust either is seeded or invades newly reclaimed sites. These trees provide song perches for birds during early growth stages and are used for nesting and cover by birds such as field sparrows (*Spizella pusilla*) in later stages (Fig. 4).

Not only is plant diversity important to bird species but the spatial configuration (strategy of planting) appears to have influence on bird composition. If reclamation procedures included creating open areas separated by sections of dense cover (hedgerows, for instance), then avian use can increase.

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98.
Extending the Seasonality of Growth of Hill Land Pastures

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The growth of hill pasture in Britain is highly seasonal, there being very little leaf growth for six months and 75% of total annual growth produced within three months of the year. Newbould (1974a) has shown that this applies equally to unimproved indigenous pasture and to pasture improved by grazing control, fertilization, and the introduction of clover (Fig. 1). Animal stocking rates in the hills are, therefore, low, since pasture growth is very poor at precisely those periods of the year when animal nutrient requirements are high and bought-in winter food is expensive. Hence, summer pasture production is undergrazed, and the consequent accumulation of mature and senescing herbage seriously reduces pasture quality in the succeeding autumn, winter, and spring (Eadie, 1968). It is thought that the accumulation of dead and decaying leaf tissue also reduces the rate of growth of young and nutritious herbage in the spring, possibly by reducing the rate of pasture photosynthesis (Newbould, 1974b). As a result of low herbage quality and pasture growth, grazing animals are often poorly nourished prior to mating and throughout pregnancy and early lactation. Consequently, fertility levels and birth weights are low and mortality rates high in grazing animals (Gunn, 1967).

The major factor causing the short growing season is thought to be temperature (Alcock and Lovett, 1968). Cooper and Breese (1971) have reported that the threshold soil temperature for utilizable growth is 5 to 6 C. Mean soil temperatures in the hill areas of eastern Britain from October to April rarely exceed 6 C and in the west are only a degree or so higher than this threshold value. There is, however, considerable inherited variability in the growth of grasses at low temperatures and this might be exploited to extend the growing season of hill pastures in Britain as shown in Fig. 2. Grasses from southern Europe and northern Africa, which exhibit relatively good winter growth in Britain, are potentially useful in this respect, but are not frost-hardy (Cooper, 1963; Lorenzetti *et al.*, 1971), while grasses from northern Europe, especially from continental climates, are frost-hardy, but produce little winter growth as a result of strict winter dormancy (Cooper, 1964). Little investigation has been made of variations in the low temperature growth of both grasses and clovers from northerly latitudes, particularly from northern maritime regions where indigenous species would be expected to show some potential for growth at low temperatures, together with adequate cold hardiness.

MATERIALS AND METHODS

Several ecotypes of *Agrostis tenuis*, *Festuca rubra*, *Lolium perenne*, and *Trifolium repens* were collected from a range of environments in the west of Scotland, the north of England, and the west coast of Norway. A limited number of populations of *Festuca rubra* were also obtained from Iceland. Collecting was concentrated in localities where indigenous ecotypes

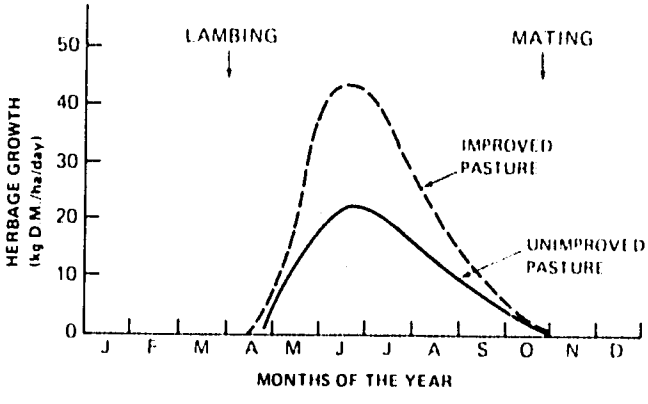

Figure 1. Seasonality of growth of hill pastures (after Newbould, 1974a).

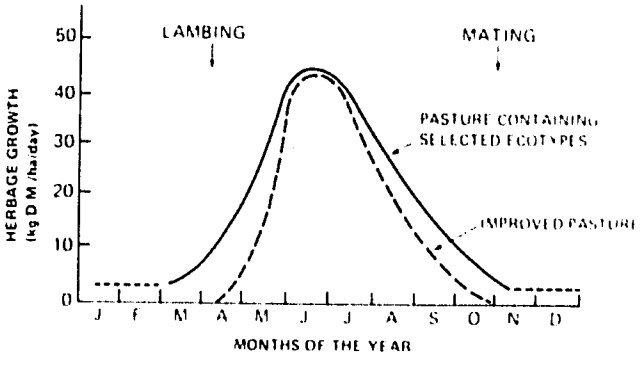

Figure 2. Possible extension of the seasonality of hill pasture production by introducing ecotypes adapted to low temperatures.

may be expected to be adapted to low temperatures and where natural selection may have favored ecotypes which are not innately winter dormant and yet are winter hardy.

Ecotypes of the four species mentioned above were tested for growth at low temperatures in low temperature cabinets operating at 0 ± 2°C. Fluorescent lights with a 6- or 10-hour photo-period gave a low light intensity of 50–60 Wm^{-2}. Plants of similar size and development of each ecotype were transferred into individual 7.5 cm pots containing John Innes No. 2 compost and allowed to root. Plants from the cultivars S59 (*Festuca rubra*), S24 (*Lolium perenne*), and S184 (*Trifolium repens*) which are commonly sown in upland pastures of Britain, were potted in the same way and used as controls. Then 8 or 10 pots per ecotype were randomly placed in the low temperature cabinets at Wylam, Northumberland. A duplicate set of *Festuca rubra*, *Lolium perenne*, and *Trifolium repens* plants was placed out of doors at Wylam for comparison with the growth of the ecotypes in the cabinets. After two weeks of acclimatization, the length of each lamina on all the grass plants and the length of each stolon on the clover plants, both in the cabinets and outside, was measured. These measurements were repeated weekly for four to six weeks. Cooper (1973) has found that leaf growth of grasses at low temperatures and short days is based primarily on changes in leaf length.

All the ecotypes, including the cultivars, were grown as spaced plants at the Redesdale Experimental Husbandry Farm in an upland area of Northumberland, 230 m above sea level. Records show that winters are long with mean soil temperatures below 6°C from November to April at this site. The leaf lamina and stolon lengths of the ecotypes of *Lolium perenne* and *Trifolium repens* were measured six times at intervals of one week during the winter of 1975–76.

The rates of photosynthesis and dark respiration of two *Festuca rubra* ecotypes were measured at 5 and 2°C by placing batches of six tillers of each ecotype in a chamber having a transparent perspex top. The chamber was submerged in a constant temperature water bath and formed part of a closed air circulation system in which a Grubb Parsons infrared CO_2 analyzer was included. Further details of this method are given in Ollerenshaw *et al.* (1976).

RESULTS AND DISCUSSION

The results of only a few of the most interesting ecotypes are presented in this paper. Certain ecotypes of *F. rubra* and *L. perenne* exhibited significantly higher ($P < 0.001$) leaf extension rates than the commercial varieties S59 and S24 when grown in pots under conditions of low light and temperature within cold cabinets (Tables 1 and 2). Similar results were found when these ecotypes were grown outside in pots under the winter lowland conditions of the Tyne Valley. Ecotypes of *L. perenne* which showed good leaf extension rates at low temperatures in pots also grew well as spaced field plants under the harsh winter conditions at Redesdale (for example ecotype 78—Table 2). However, we have found the occasional ecotype of *L. perenne* (Ecotype 72 in Table 2), which has exhibited good winter growth at Redesdale but produced relatively poor growth under the controlled conditions of the cold cabinet.

Some of the Norwegian ecotypes of *A. tenuis* have also produced high leaf extension rates in the cold cabinets (Table 3). There are no commercial varieties of *A. tenuis* which could be grown under hill conditions in Britain since this species has been

TABLE 1. Mean rates of leaf lamina extension of four *Festuca rubra* ecotypes over four weeks

Ecotype	Leaf Extension Rates (mm leaf lamina/week) Cold Cabinet	Winter Field Conditions (Tyne Valley, 1975)
Cultivar S59	19.2	16.7
09 (Northern)	31.2	26.5
45 (Britain)	34.4	27.9
Iceland	29.6	29.5
LSD (P = 0.05)	5.4	5.8

TABLE 2. Mean rates of leaf lamina extension of three *Lolium perenne* ecotypes over six weeks

Ecotype	Leaf Extension Rates (mm leaf lamina/week) Cold Cabinet	Winter Field Conditions 1976 Tyne Valley (lowland)	Redesdale (upland)
Cultivar S24	45.0	85.8	32.8
78 (Northern)	66.7	121.3	48.6
72 (Britain)	35.9	87.3	43.0
LSD (P = 0.05)	8.7	14.4	8.5

TABLE 3. Mean rates of leaf lamina extension of six *Agrostis tenuis* ecotypes over six weeks

Leaf Extension Rates (mm leaf lamina/week)	Norwegian Ecotypes 13	14	29	36	38	41
Cold cabinet	56.8	58.7	72.0	53.1	72.6	52.8

considered to be very late in spring growth (Newbould, 1974a). However, the leaf extension rates of the *A. tenuis* ecotype shown in Table 3 compare very favorably with that of the *L. perenne* cultivar, S24 in Table 2. S24 is known to be an early cultivar and shows good growth at low temperatures (Peacock, 1975).

White clover (*T. repens*) is an essential constituent of upland pastures, since expenditure on nitrogenous fertilizers is not fully justified in a low budget system such as hill farming. Existing clover cultivars start growth late in spring and are thus at a competitive disadvantage. They are also slow in supplying organic nitrogen to associated grasses. We have found a number of *T. repens* ecotypes capable of relatively good growth at low temperatures under controlled cold cabinet, lowland, and upland conditions (Table 4). Other examples have been cited by Ollerenshaw (1975). Ecotype 24 originated from a lowland site and proved to be frost sensitive, having been almost completely killed out under hill conditions (Table 4). Conversely, ecotype 102 grew well at Redesdale but was not outstanding in growth under the conditions of the cold cabinet.

When growth is adapted to low temperatures there is evidence that there are associated changes in the rates of photosynthesis and dark respiration (Pisek, 1973). The higher dark respiration rates of plants from high altitude and/or latitude (Stewart and Bannister, 1974) are thought to compensate for the lower temperatures and shorter seasons experienced (Mooney, 1963). The more cold adapted Icelandic ecotype had a greater excess of photosynthate than the Northumberland ecotype at 5C (Table 5). Similar results were found at 2 C (Ollerenshaw *et al.*, 1976). The higher respiration rate may indicate a greater ability to use photosynthate for growth at low temperatures. Measurements of photosynthesis and dark respiration rates may provide a rapid laboratory screening method to test the ability of plants to grow at low temperatures.

Some of the grass and clover ecotypes which we have studied have the ability to grow well at low temperatures and low light intensities and may provide useful genetic material for improving hill grassland production by extending the growing season. There also are indications that some of these ecotypes may be cold tolerant. Cooper (1964) showed that grasses collected from continental climates are frost-hardy but produce little winter growth. An inverse relationship between growth at low positive temperatures and cold tolerance at sub-zero temperatures is thus thought to exist in temperate grasses (Cooper, 1973). However, there are some members of the Gramineae, winter rye for example, in which the combination of winter growth and cold tolerance already exist (Breese, 1964). We suggest that there are natural ecotypes of grasses and clovers from northern maritime regions which may also possess this combination of characters.

TABLE 4. Mean rates of stolon elongation of four *Trifolium repens* ecotypes over six weeks

Ecotype		Stolon Extension Rates (mm stolon/week) Winter Field Conditions, 1976		
		Cold Cabinet	Tyne Valley (lowland)	Redesdale (upland)
Cultivar S184		2.18	2.26	1.16
77	Northern Britain	3.22	4.02	2.79
24	Northern Britain	4.09	3.45	0.20
102	Northern Britain	2.00	2.50	1.91
LSD (P = 0.05)		0.79	0.62	0.56

ACKNOWLEDGMENTS

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TABLE 5. Rates of photosynthesis and dark respiration of two *Festuca rubra* ecotypes at 5° C

Ecotype	Photosynthesis (P)	Dark Respiration (R)	P/R
		mg CO_2/g dry weight/hour	
Central Iceland (I)	17.77	1.41	12.59
Northumberland coast (02)	11.11	1.26	8.80
LSD (P = 0.05)	3.20	0.15	

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DISCUSSION

R. Cuany (Colorado, USA). Do you have plans to put these into seed production?

Ollerenshaw. Yes, the next phase, as far as we're concerned, is to cross a number of genotypes within each ecotype and to produce seeds from this and grow it in miniplots to see how these perform in upland situations. Past that stage, we will hand it on, I think, to the Welsh Plant Breeding Station, since we are not actually stock breeders, we're more agronomists and physiologists.

G. Jung (Pennsylvania, USA). Another strategy might be employed here: instead of extending the growth period for a species, you might think about the possibility of utilizing other species that readily grow at low temperatures. I had in mind rye or winter wheat or kale, red turnip, and with the advent of no tillage equipment, at least under our country's conditions, it would seem to be a strategy that should be looked into. How would that fit into your situation?

Ollerenshaw. I agree that this should be looked into and in fact as far as Britain is concerned, we are looking into this. Several experiment stations are growing "100-day" turnips—very fast growing over a short period of time—and possibly one or two have interest in winter ryes as well. But it is an expensive process as far as turnips are concerned, of course. It's a one-up job and they have to cultivate again next year. As far as winter rye is concerned, if you try to keep this for a long period of time I think you're going to get problems of adaptation to hill land conditions and you may get native species coming back in. It would be interesting, also, to look at the possibility of using different species for different purposes at this time of year. If we could, say, grow timothy for high production in the spring and not have to graze it in the autumn and grow another species for production in the autumn like, say, perennial ryegrass, I think that would be best.

99.

Ecological and Production Aspects of a North- and South-Facing Slope Pasture System

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Land areas unsuitable for tillage represent a major grassland resource in the Appalachian Mountain region of the eastern United States. Although such areas are important in themselves, more effective use of the steeper hill land areas occurs when they are combined with land suitable for the production of machine-harvestable forage crops for winter feeding. Such combinations are synergistic both in terms of land use and the production of beef cattle and sheep.

Technology required for the effective use of tillable areas for production of forages is well established. This is not, however, the case with hill lands where maintenance of soil fertility and the effect of such factors as slope, elevation, and exposure play important roles in determining use and productivity. However, detailed information regarding yield responses and management systems as affected by slope orientation in hill land is very limited (Bennett *et al.*, 1972; Grant, 1968). Chang (1968) suggested that slope exposure is a more important factor in the middle latitudes than in the polar regions and will exhibit a greater effect in the summer season because of the ratio of diffuse to total radiation during mid-latitude winters and year around in the polar regions.

South-facing slopes commonly exhibit much greater soil temperature extremes, producing a more adverse microclimate for cool-season or temperate species. Pool (1914) reported soil temperature differences of 30 C between north- and south-facing slopes in Nebraska. Maximum summer soil temperature at 2.5 cm below a bluegrass sod was commonly 8 to 10 C lower on a north-facing compared to a south-facing slope in West Virginia (Bennett *et al.*, 1972). Brown (1939) reported that the optimum temperature for bluegrass root and rhizome growth was between 10 and 15 C. When soil temperatures increase above 20 C underground growth of bluegrass is extremely limited; soil temperatures above 25 C usually result in summer dormancy.

Regardless of the inadequacies, bluegrass is well adapted to the cool humid regions of the northeastern United States. During favorable environmental periods bluegrass pastures can and do provide satisfactory levels of animal performance and persist even under unfavorable management systems (Blaser *et al.*, 1956).

Low soil fertility levels are common in humid hill lands of the United States. The use of the helicopter as an agricultural implement has made the amendment of plant nutrients on difficult terrain feasible and practical. Return from improvements in soil fertility must be adequate to support continued investment. To this end, appreciation of such items as slope, elevation, and exposure is necessary in developing management programs.

The purpose of this study was to examine hill pastures as an integral unit of forage-grazing systems, with a major emphasis on the effect of slope exposure in the overall system performance.

MATERIALS AND METHODS

A hill area with a southern exposure was divided into six pastures of 0.57 ha each. Similar areas were established on a northern exposure. However, the area involved reflected a slight eastern or western influence. The slope of these areas varied from 15 to 40% within pastures. Differences in slope among pastures on an exposure were considered in establishing replicates. After appropriate soil amendments of lime, phosphate, and potassium were made, the hill pastures were seeded to Kentucky bluegrass (*Poa pratensis*) and common white clover (*Trifolium repens*). A year (1966) was allowed for establishment during which time the pastures were grazed by cattle.

The area between the two exposures is gently rolling and suitable for mechanically harvested forage production and/or grazing. This area, designated as meadow, was divided into twelve units of 0.85 ha each. These units were arranged into four replicates. Units within these replicates were seeded to Kentucky bluegrass, orchardgrass (*Dactylis glomerata*), or Kentucky 31 fescue (*Festuca arundinacea*). Two replicates were assigned to each hill pasture exposure to form three pasture-forage production systems as outlined in Tables 1 and 2.

Location of the site is about 39.5° N and 79.8° W at an elevation of 550 m. Annual precipitation of 1 150–1 300 mm is reliable with 50 to 60% of this falling during the frost-free period, May 1 to October 1. About 25% of the annual precipitation is received in the June–August period during which time highest annual temperatures are usually recorded (mean maximum of 10.2–14.5 C). Meterological monitoring stations were located on each exposure.

TABLE 1. Design of trials, pasture and meadow arrangements

Hill Pastures			Associated Meadow Area		
Exposure	Number	Size (ha)	Grass (species)	Number	Size (ha)
South	6	0.57	Fescue	2	0.85
			Orchard	2	0.85
			Bluegrass	2	0.85
North	6	0.57	Fescue	2	0.85
			Orchard	2	0.85
			Bluegrass	2	0.85

TABLE 2. Utilization schedule

Date	Hill Pastures	Meadow Areas
April 15	Begin grazing (S.Ex)	
May 1	Begin grazing (N.Ex)	
June 1-15	Graze	Hay harvest
July 1	Rest	Graze and/or harvest
July 30	Graze	Rest
August 15	Graze	Harvest surplus
August 15-30	Rest	Graze
September 1	Graze	Rest
October 1-15	Terminate grazing	Rest

Spring grazing on the hill pastures was begun when the available dry matter reached approximately 1 000 kg dry matter/ha. On this basis, grazing of the southern exposure pastures began about April 15, whereas a representative date for the northern exposure pastures would be May 1.

During the late winter each meadow area received an application of 60 kg N/ha. These areas were harvested in early June and then received a topdressing of 60 kg N/ha. About 14 days after harvest, recovery regrowth measured 12 to 15 cm and grazing was begun. Each area was divided by an electric fence to permit rotation or the conservation of one-half of the area for later harvest, if conditions permitted. Rotation to the hill pastures was largely determined by available dry matter, but since recovery was more rapid in some pastures than in others, the criterion of 750 kg/ha of available herbage could serve only as a guide. After the initial grazing of the hill pastures, the grazing rotation approximated a ratio of four weeks on meadow and two weeks on the hills. Trials were ended during the first weeks in October. The grazing, rotation, and harvesting schedule is summarized in Table 2.

Steers used in these trials were obtained as weaned calves at about seven months of age and were wintered to gain about 0.25 to 0.35 kg/day. Accordingly, the cattle were about 14 to 17 months old and weighed about 235 kg at the beginning of a trial. The animals were sorted into outcome groups on the basis of winter gains and bodyweight. Three uniform units were composed and assigned at random to treatments and pastures. Body weights were obtained at the beginning and ending of trials and whenever grazing areas were rotated. A set stocking rate of three steers for each combination of hill pasture and meadow was maintained throughout.

RESULTS

Difference in response as a reflection of exposure regularly permitted earlier grazing on the southern exposure. The mean date for beginning of grazing on the southern exposures was April 22, whereas the date for the northern exposure pastures was 17 days later, May 7. This first grazing of the hill pastures ended on July 1, when the steers were rotated to the meadow regrowth. The mean ending date for grazing was October 11. Distribution of grazing between the hill pastures and meadow areas is given in Table 3. Under the procedures followed in these trials about 60% of the grazing days were provided by the hill pastures. The additional 17 days of grazing provided by the southern exposure pastures is reflected in the 13% difference in grazing days and 20.5% difference in bodyweight gain per ha (Table 4).

TABLE 3. Distribution of grazing between hill pastures and meadows

Year	Exposure	Hill Pasture Days	Hill Pasture Percent	Meadow Days	Meadow Percent	Total Days
1967	South	108	60	70	40	178
	North	89	56	70	44	159
1968	South	106	58	77	40	183
	North	100	61	65	39	165
1969	South	100	60	67	40	167
	North	87	56	67	44	154
Mean	South	104	59	71	41	176
	North	92	58	67	42	159

TABLE 4. Influence of exposure on hill pasture productivity[a]

Exposure	Grazing (days/ha)	Bodyweight Gain (kg/ha)
South	560	434
North	494	360

[a]Each value is mean of 18 observations. Differences significant $P < .05$.

In keeping with the design of these trials, the use of the meadow areas for grazing was complementary to the full use of the hill pastures. Accordingly, the contribution was uniform for each of the grass species involved. Each of the grasses provided 169 steer grazing days per ha and was equivalent to about 40% of the total grazing period. Bodyweight gains produced from the three grasses were not significantly different. Yield of dry matter per ha was not significantly different between fescue and orchardgrass areas. However, the bluegrass areas produced significantly less harvested dry matter. If this preserved forage is translated into bodyweight gain on the basis of 25:1, the fescue and orchardgrass systems were more productive ($P < .05$) than bluegrass systems (Table 5).

Each hill pasture combined with a meadow area formed a system. Each of the possible combinations of grasses with a hill exposure was replicated, thus forming three systems for each exposure, or in effect six systems. Since the contribution to each system of all meadow areas in terms of grazing days was the same, results have been summarized in Tables 5 and 6 in terms of north- or south-facing systems without regard to species of grass. Treatment of the results in this way shows that the systems based on south-exposure hill pastures had a mean production of 115 kg/ha whereas the north hill pasture systems produced 102 kg/ha. The mean daily body weight change for both systems is almost identical. This obviously emphasizes that the differences between south-facing and north-facing hill pasture productivity are largely a reflection of early spring plant response (Table 7).

Full assessment of the grazing-forage production systems studied in these trials should include the utilization of the preserved forages by wintering cattle. To this end, the weaned calves procured in the fall for the subsequent grazing season were fed the harvested forages. The forages were fed essentially *ad libitum* (2% body weight/day) with appropriate adjustments to prevent waste and accommodate for temperatures below 0 C.

Temperatures of −15–20 C are not uncommon during December–February. A supplement composed of ground corn, urea, and minerals was fed at a level of 1 kg per animal. Under these conditions body weight gains produced from the three grasses were essentially the same; however, date of harvest did influence consumption and wastage.

The performance of pastures and the productivity of associated meadow areas is combined with the

TABLE 5. Meadow productivity, 1967–68–69

	Grazing		Harvested		
Meadow Grass	Steer Days/ha	Bodyweight Gain (kg/ha)	Hay (kg/ha)[a]	Bodyweight[b] Gain Equivalent (kg/ha)	Total Bodyweight Gain (kg/ha)
Fescue	169	135	7754	310	445
Orchard	169	123	7207	288	411
Bluegrass	169	139	5585	223	362

[a]85% dry matter.
[b]25 kg 85% dry matter forage equivalent to 1 kg bodyweight gain.

TABLE 6. Mean bodyweight gains[a]

Year	South-facing Hill Systems			North-facing Hill Systems		
	Initial	Ending	Gain	Initial	Ending	Gain
			Kg			
1967	218	344	126	228	332	104
1968	219	342	123	214	333	119
1969	268	365	97	279	363	84
1967–69	235	350	115	241	342	102

[a]Each value represents mean of 18 steers.

Table 7. Grazing days and daily bodyweight gain

Year	South-facing Hill Systems		North-facing Hill Systems	
	Grazing Days	Mean Daily Gain	Grazing Days	Mean Daily Gain
		kg		*kg*
1967	178	0.71	159	0.65
1968	193	0.64	175	0.68
1969	167	0.58	154	0.54
Mean	179	0.64	162	0.63

winter performance to determine the performance of south-facing and north-facing systems on an animal basis. A standard grazing period of 170 days, a standard winter feeding period of 195 days with a mean animal body weight of 215 kg, and a standard winter feeding level of 4.3 kg/day are used to estimate requirements for a three-steer unit such as those used in the grazing trials. The estimated requirements based on these standards are compared to the actual performance of the south-facing and north-facing systems (Table 8). The only deficiency suggested by this comparison is a small deficit in grazing days provided by the north-facing systems and this is a reflection of the delay in the beginning of grazing on the north-exposure pastures.

TABLE 8. Annual system performance and estimated requirement

System	Grazing (days/ha)	Dry Feeding (days/ha)
South-facing	394	456
North-facing	348	457
Estimated requirement[a]	359	[illegible]2

[a]Based on a 1.42 ha system composed of 0.57 ha hill pasture and 0.85 ha meadow supporting three steers for a 170-day grazing season (Apr. 15–Oct. 2) and 195-day dry feeding period (Oct. 3–Apr. 14) with mean weight of 215 kg and feeding level of 4.3 kg per day.

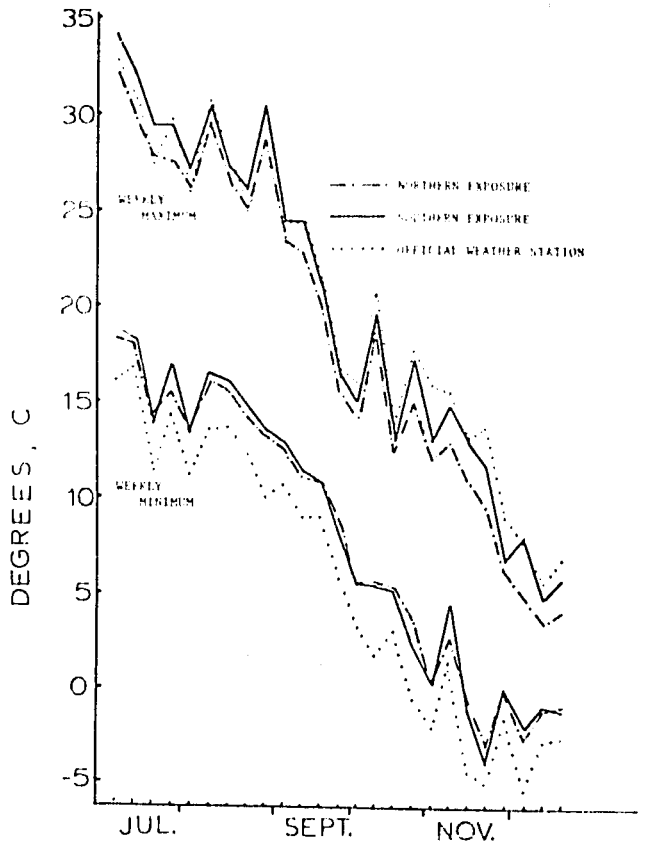

Figure 1. Mean weekly temperature (1966).

Soil temperature data for July to December, 1966, are illustrated in Fig. 1. The temperatures shown are the weekly average maxima and minima from a soil depth of 2.0 to 2.5 cm. The weekly maximum soil temperatures between the two slopes did not exceed 3 C during this time period. The reduced magnitude of these differences compared to the data of Bennett *et al.* (1972) is a reflection of the overall cooler climate and higher elevation of this site. (The effects produced by the grazing animal were not a factor in the study of Bennett *et al.*) The weekly minimum temperatures between the two exposures were very similar, usually not exceeding 1 C. There was a greater difference in the weekly minimum temperatures between the official weather station and the field sites than between the two exposures or field sites.

The maximum daily soil temperature differences occurred during July. When the maximum daily air temperature exceeded 30 C, the soil temperatures on the southern exposure were frequently 2 to 5 C higher than on the northern exposure (Fig. 2). When the maximum air temperatures were below 30 C, the difference in maximum soil temperatures between the two exposures was very small. Daily minimum temperatures were nearly the same for both slopes, but often ranged from 1° to 6° C higher than the official weather station minima. The higher

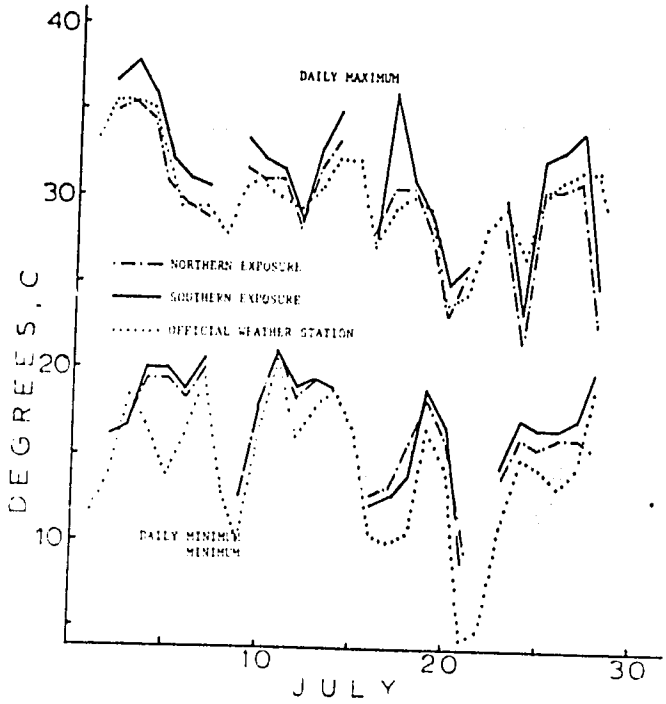

Figure 2. Daily maximum and minimum soil temperatures (2.0 to 2.5 cm) compared to the official weather station values during July, 1966.

minimum soil temperatures at the pasture site is a reflection of the insulating effect of the vegetative sod cover.

Although significant differences in soil temperatures between the two exposures were found, the magnitude of these differences was not as great as had been expected. A major, unobstructed air drainage system from a southwesterly to northeasterly direction was noted but not measured. This would partially explain the lower soil temperature maxima that were recorded for this site.

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DISCUSSION

J. Scholl (Wisconsin, USA). You don't have a check pasture in this situation. Could you estimate what would be the production from an open type permanent pasture in the area?

Henderlong. My guess would be less than half the way they're managed now.

Scholl. Are you disturbed that your daily gains are, say, less than about a pound and a half? Is that what you'd expect from a pasture?

Henderlong. I would say that I was reasonably well satisfied.

Scholl. I make that comment because those are the kinds of gains we're getting in Wisconsin now on similar pastures which are low in energy.

Henderlong. Ideally we wanted to go with a cow-calf herd rather than fattening steers in this particular situation, but there were other problems and I think we were trying to look at what we could do with the system rather than pursuing maximum daily gains.

O. Bennett (West Virginia, USA). These two pastures are entirely different from a service standpoint. First of all, the soil types are quite different—the northern exposure was a shallow phase of a very stony soil and a much steeper slope than the southern exposure and I think production on the southern exposure would more nearly equal that of lowland conditions. You also had a lot of rocks outcropping there that would reflect in the yields so it's really not a valid comparison from a service standpoint. I'm familiar with that situation and I didn't think it was a very good set-up but sometimes it's the only thing we can find. I know I looked for a long time before I could find north and south exposures with the same soil type and similar soil conditions and the same slope, so I know what the problem was.

Henderlong. From Dr. van Eck's soil inventory of the site it appeared that the northern exposure had somewhat of a deeper soil than the southern slope or the southern exposure. Now the exposure and the degree of slope was different, I do agree, and you did not have the rock outcrops on the south exposure that we had on the north. So there were microclimate differences due to the physical location. The soil on the south-facing slope was basically a DeKalb-Earnest intergrade; on the north-facing slope it was primarily Gilpin.

Bennett. Yes, these are quite different in their productivity.

100.

Seasonal Yield Distribution, N Fertilizer Response and Utilization of *Poa pratensis* on North- and South-Facing Slopes*

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Annual yield response of Kentucky bluegrass (*Poa pratensis*) to various N and NPK fertilization regimes is well documented for the temperate regions of the world (Bennett *et al.*, 1972; Dotzenko, 1961; Kaltofen *et al.*, 1966; Kresge and Younts, 1962; and Walker *et al.*, 1963). Yield responses to N rates exceeding 400–500 kg N/ha are relatively common for adapted cool-season grasses (Kaltofen *et al.*, 1966). However, only limited descriptive data are available on forage grass yield responses in the complex microclimate induced by mountainous or hill land terrain (Bennett *et al.*, 1972).

In hill land pasture grazing programs, seasonal distribution of the herbage production may be as important as total annual yields. Cowling (1966) suggested that the response of grass swards to N fertilizer may be better understood by examining both the dry matter and N yields. He further suggested that we know little about the potential response to N at different seasons. Kaltofen *et al.* (1966) reported that single or split applications at the same annual N rate generally produced similar total yields. However, the split treatments resulted in more even seasonal production, especially at the lower and intermediate annual N levels. Wedin (1974) indicated that most cool-season grasses in the temperate regions produce approximately two-thirds of the total annual dry matter at the first harvest. Mays and Terman (1969) indicated that this could be decreased to about 55% with split applications of soluble N fertilizer materials.

Recent data of Bennett *et al.* (1972) suggest that slope orientation can greatly affect total yield response to N and seasonal yield distribution in hill lands. This paper more fully describes the seasonal distribution of the annual herbage production and dry matter production per unit of N applied as affected by slope orientation.

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MATERIALS AND METHODS

Ammonium nitrate was applied annually at 0, 112, 224, 448, and 672 kg N/ha in single or split applications to an established bluegrass sod. The treatments were replicated three times on both a north- and south-facing slope located directly opposite each other and less than 90 m apart. Soil on both slopes was a Gilpin silt loam (Typic Hapludult) with slope inclinations of approximately 35%. The experimental site was near Morgantown, W. Va. (39°39′ N, 79°55′ W) at an elevation of approximately 382 m.

The forage was harvested by clipping a 95 cm strip through the center of each plot at a height of 5 cm. Yields were calculated on an oven-dry basis (65 C). Additional procedural details were previously reported (1972).

RESULTS AND DISCUSSION

Nitrogen application rates and slope exposure greatly affected the total annual yields of the bluegrass (Table 1). Total yields were consistently greater on the north-facing slope. Also, the yield response to all N treatments was significant for both slope exposures each year except on the south slope in 1966.

The 45-year mean annual total rainfall for this location is 106.8 cm, with 76.4 cm received during the growing season (March through October). Total rainfall in 1966 was only 73.5 cm. This was an annual deficit of 25.3 cm, but 21.8 cm of this deficit occurred during the growing season. Yield responses to N were the largest during the 1967 season, especially on the north-facing slope. Rainfall during the 1967 growing season was 5.2 cm above the 45-year average. For 1968, rainfall was intermediate to the two previous seasons, with a seasonal deficit of 8.4 cm and an annual deficit of 16.3 cm.

Seasonal distribution of the forage produced was markedly affected by the slope exposure. In 1966 and 1968, all of the total annual yield for the southern exposure was produced early in the growing season, i.e., the first harvest date (late May). The lack of any appreciable aftermath production reflects the

TABLE 1. Total annual bluegrass yields and first harvest component (percentage) as affected by slope exposure and rate and time of N application

Annual N Treatment (kg/ha)	Yield and First Harvest Component, for Years and Slope Exposure											
	1966				1967				1968			
	North Exposure		South Exposure		North Exposure		South Exposure		North Exposure		South Exposure	
	Total (kg/ha)	1st Harv. (%)	Total (kg/ha)	1st Harv. (%)	Total (kg/ha)	1st Harv. (%)	Total (kg/ha)	1st Harv. (%)	Total (kg/ha)	1st Harv. (%)	Total (kg/ha)	1st Harv. (%)
0	3052e[a]	63	819	100	2856g	62	1212e	65	4219d	83	1453d	100
112	7781abc	70	1187	100	6036f	73	3093abcd	94	5685c	76	3956bc	100
224	8539a	63	857	100	6705ef	68	2980bcd	93	7121a	75	4006abc	100
448	8691a	64	1256	100	8306cd	58	3519abc	94	6321abc	73	4643ab	100
56 + 56	7885abc	67	1486	100	6074f	60	2620cd	90	6253abc	77	3216c	100
112 + 112	6963c	67	1459	100	8345cd	54	3380abc	92	6861ab	69	4026abc	100
224 + 224	8084a	64	1719	100	11585a	66	3909ab	87	6737ab	73	4713ab	100
336 + 336	7462bc	60	1188	100	7604de	54	3105abcd	90	6238abc	81	4360ab	100
56 + 56 + 56 + 56	5912d	67	1098	100	8553bcd	47	2348d	83	6789ab	72	4829ab	100
112 + 112 + 112 + 112	7872abc	64	1147	100	9108bc	53	3081abcd	91	6089bc	76	4265ab	100
168 + 168 + 168 + 168	8361ab	66	1170	100	9448b	49	4081a	95	6313abc	75	4973a	100
Mean	7327wx[b]	65	1217z	100	7693w	59	3030y	89	6239x	75	4040y	100

[a]Values within the same column having the same letter are not significantly different at the .05 confidence level.
[b]Means with the same letter in this row are not significantly different at the .01 confidence level.

higher summer temperatures, higher net radiation levels, and higher evapotranspiration rates on the southern exposure (1972), in addition to the limited rainfall. Even during seasons of near "normal" incident rainfall (1967), approximately 90% of the total annual yield on the southern exposure was produced in the first harvest. Data from the northern exposure indicated that an average of 60–75% of the total annual yield was produced during the spring period (first harvest). Nitrogen rate and time of application altered the seasonal yield distribution considerably for the northern exposure. In general, split N applications decreased the first harvest component to approximately 50% with no adverse effect on the total annual yield in the year in which rainfall was not limiting (1967). In years of limited rainfall (1966 and 1968) total annual forage yields tended to be reduced with the four-increment split application.

The seasonal yield distribution for 1967 is shown in Table 2. Only two cuttings were obtained from the southern exposure, even though incident rainfall was near "normal." On the northern exposure, cuttings after the first harvest frequently represented 10–20% of the total annual yield for each of the harvests. The data indicate that split N applications can result in more uniform seasonal growth without adversely affecting total annual production at the intermediate rates of N application. At the higher N application rates (448 and 672 kg N/ha), however, split applications did not improve the seasonal distribution over the intermediate N rates.

Applications of N above 112 kg N/ha on a southern exposure cannot be justified, based on the annual yield data (Table 1), dry matter production/unit of applied N (Table 3), and percentage of applied N recovered in annual forage yields (1972). Because of the unique and adverse microclimate interrelationships on a southern exposure, production will usually be near maximum with a single application of up to approximately 100 kg N/ha in early spring. If the seasonal rainfall is adequate, a supplemental application of 50–100 kg N/ha after the first harvest may be justified.

On the northern exposure, applications of 200–400 kg N/ha were beneficial, depending upon the amount of seasonal rainfall. Use of the N fertilizer was most efficient with the lower annual rates. Nevertheless, reasonable production/unit of N applied was obtained with rates up to 448 kg N/year on the northern exposure (Table 3). Mean dry matter production/unit of N applied was 10 times greater in 1966 and 2.5 times greater in 1967 on the northern exposure than on the southern exposure. The improved production /unit of N on the southern exposure for 1968 was likely due to N carryover from the previous two years.

The data clearly illustrate that forage production is greatly influenced by the microclimate induced by hill land conditions. Bluegrass was more responsive to and more efficient in N fertilizer use on the cooler northern exposure than on the southern exposure.

TABLE 2. Seasonal yield distribution of bluegrass as affected by slope exposure and rate and time of N application (season with near normal rainfall—1967)

Annual N Treatment (kg/ha)	Exposure	Total Yield (kg/ha)	Harvest Date May 22	July 6	Aug. 8	Nov. 1
				% of total yield		
0	North	2 856	62	22	12	4
	South	1 212	65	35	—	—
112	North	6 036	73	17	6	4
	South	3 093	94	6	—	—
56 + 56	North	6 074	60	25	10	5
	South	2 620	90	10	—	—
224	North	6 705	68	20	10	2
	South	2 980	93	7	—	—
112 + 112	North	8 345	54	23	16	7
	South	3 380	92	8	—	—
56 + 56 + 56 + 56	North	8 553	47	19	22	12
	South	2 348	83	17	—	—
448	North	8 306	58	15	13	14
	South	3 519	94	6	—	—
224 + 224	North	11 585	65	14	11	10
	South	3 909	87	13	—	—
112 + 112 + 112 + 112	North	9 108	53	14	16	17
	South	3 081	91	9	—	—
336 + 336	North	7 604	54	10	19	17
	South	3 105	90	10	—	—
168 + 168 + 168 + 168	North	9 448	49	15	18	16
	South	4 081	95	5	—	—

TABLE 3. Nitrogen-use efficiency of bluegrass as affected by year, slope orientation, and rate and time of application

Annual N Treatment (kg/ha)	N-use Efficiency 1966 South	1966 North	1967 South	1967 North	1968 South	1968 North
			*kg DM/kg N**			
112	3.29	42.22	16.80	28.39	22.35	13.09
224	0.17	24.50	7.89	17.18	11.40	12.96
448	0.98	12.59	5.15	12.16	7.12	4.69
56 + 56	5.96	43.15	12.57	28.73	15.74	18.16
112 + 112	2.86	17.46	9.88	24.50	11.49	11.80
224 + 224	2.01	11.23	6.02	19.48	7.28	5.62
336 + 336	0.55	6.56	2.82	7.06	4.33	3.00
56 + 56 + 56 + 56	1.66	17.02	5.07	25.43	20.10	15.30
112 + 112 + 112 + 112	0.98	14.34	4.17	13.96	8.37	5.56
168 + 168 + 168 + 168	0.70	10.53	4.27	9.81	6.98	4.16
Mean	1.91	19.96	7.44	18.67	11.51	9.43

$$^{*}\text{kg DM/kg N} = \frac{\text{Total treatment yield} - \text{0 treatment yield}}{\text{annual total N applied}}$$

TABLE 4. Correlation coefficients and regression equations for dry matter production/unit of N applied and nitrogen recovery

Year	Exposure	Correlation Coefficient	Regression Equation
1966	North	0.95	y = 9.5 + 2.529x
1966	South	0.95	y = 3.1 + 2.426x
1967	North	0.96	y = 18.6 + 2.238x
1967	South	0.99	y = 2.6 + 2.841x
1968	North	0.86	y = 12.6 + 2.795x
1968	South	0.92	y = 8.1 + 2.196x
3-year mean	North	0.94	y = 14.6 + 2.408x
3-year mean	South	0.97	y = 5.0 + 2.471x

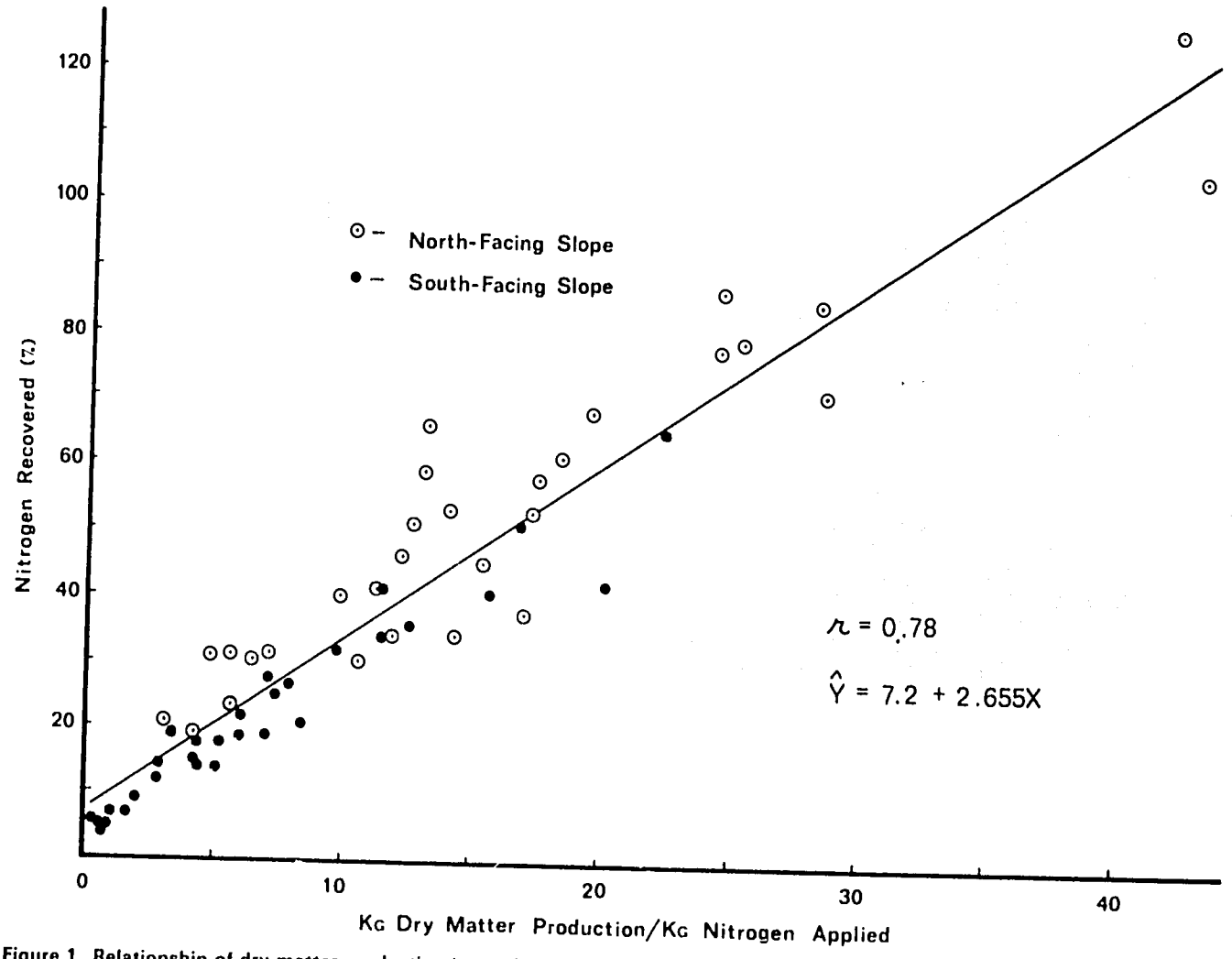

Figure 1. Relationship of dry matter production/unit of N applied and nitrogen recovery.

Forage production was also distributed more uniformly throughout the growing season on a north-facing slope, which should provide a longer grazing season in addition to a considerably higher carrying capacity.

Forage production studies are often conducted under situations in which it is not always possible to obtain herbage chemical analysis. Nevertheless, an evaluation of the relative fertilizer-use efficiency is highly desirable.

When nitrogen analysis of the herbage is not available, an estimate of the recovery of applied nitrogen fertilizer is proposed based on dry matter production per unit of applied fertilizer. This ap-

proach requires the inclusion of a check treatment (0-N) as a correction for residual or native soil N or other sources of N, such as rainfall.

The apparent relationship between dry matter production/unit of N applied is much better when evaluated for each slope exposure (Table 4) than when combined (Fig. 1). This, again, is a reflection of the different microclimates induced by the hill land conditions.

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DISCUSSION

G. Voigtlander (Germany). If you use little or no nitrogen in the summer this method is not very sure, because if you have little rainfall in the summer you cannot harvest in the summer what you have lost in the spring.

Henderlong. I think our data and experience would be very similar to that. You can certainly alter the distribution, but you reach a compromise where you lose much in terms of total dry matter production even though you accomplish your objective of extending or altering the productive growing season of the species. Usually, from an economic standpoint, you lose much in terms of total dry matter production.

J. Scholl (Wisconsin, USA). In this experiment, you used the same mixture on north and south exposures and you shouldn't at this stage. Is this right?

Henderlong. No, we took the indigenous bluegrass sod that was already there. This was not seeded—it was an old, established bluegrass pasture.

Scholl. With the present state of our information, maybe we can't do anything else, but it may well be that we could have an entirely different combination on the north and south and then these differences might not be so great.

Henderlong. I agree. In fact, if you look at tall fescue, I'm sure, based on Dr. Bennett's work and personal observations, that the difference in yield productivity between the slopes would not be nearly as great as it was with bluegrass. We need to know more about the advantages and disadvantages of our forage species and then plug them into this system to take advantage of their strong points and recognize their weak points.

101.
The Utilization of Radiation Energy in Differently Managed Alpine Pastures

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The utilization and conservation of alpine pastures are matters of high public interest in Germany.

The problem of the best use of alpine pastures is judged differently by ecologists, conservationists, farmers and tourists. Therefore, there is a need for a better understanding of the various interactions within an alpine pasture ecosystem. An attempt was made to investigate an alpine pasture ecosystem in the Bavarian Alps at elevations between 1400 and 1700 m (precipitation about 1700 mm/yr, mean yearly temperature about 3 C). The utilization of radiant energy covered in this paper forms only a small part of the whole study. The research project was started in 1974 and will be continued until 1978.

MATERIALS AND METHODS

Field Trial

Fig. 1 is a plan of the study site, and Fig. 2 shows the trial which was established to find out the influence of different management treatments on the pasture ecosystem.

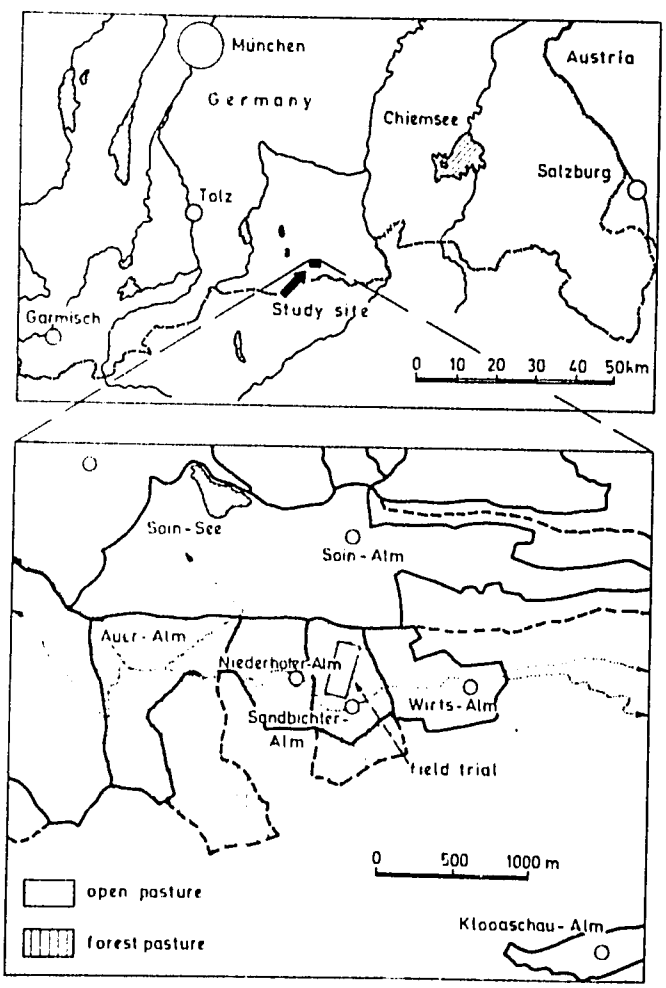

Figure 1. Location of the study site in the Bavarian Alps.

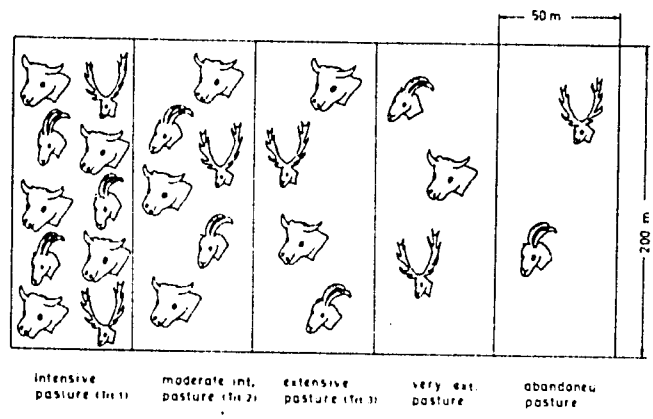

Figure 2. Field trial with five differently managed paddocks.

The efficiency of radiant energy has been studied in three paddocks up to now. Table 1 contains the most important management characteristics of the three treatments.

The study site contains three original plant communities which occur across the paddocks:

TABLE 1. Fertilization and management of three variants*

Treatment No.	Fertilization (kg/ha) N	P_2O_5	K_2O
1	60	120	140
2	—	120	140
3	—	—	—

*All paddocks listed here were rotationally grazed.

"*Crepido-Cynosuretum*," named after *Crepis aurea* and *Cynosurus cristatus*, is a pasture which has been regularly grazed.

"*Carlino-Caricetum sempervirentis*," named after *Carlina acaulis* and *Carex sempervirens*, is a pasture which has been regularly but not intensively grazed and which has not recently been fertilized.

"*Seslerio-Caricetum sempervirentis*," named after *Sesleria coerulea* and *Carex sempervirens*, is a natural grassland which occurs above the treeline and has been grazed only sporadically.

Investigation of Primary Production

The above ground phytomass was harvested twice a year from 10 parcels per paddock; 12 squares of 30 square cm were collected per parcel. It was weighed, then dried and pulverized. The remaining water was determined and the dry matter per ha was calculated. Portions of the material were pressed into tablets of approximately 1.1 g (Lieth, 1968). The oven-dry tablets were weighed and the organic matter was burned using calorimeter bombs. The method used was described in detail by Runge (1973a).

Measuring Global Radiation

Global radiation was measured by a Moll-Gorzinsky instrument and recorded at intervals of 45 secs. The sums of radiant energy for optional intervals can be identified by planimetry.

Calculation of the Efficiency of Net Primary Production

Radiant energy was summarized from the beginning of the vegetation period to the first cut and from the first cut to the second cut. The very small regrowth of phytomass after the second cut was not taken into consideration. The efficiency is calculated by dividing the energy content of the phytomass harvested by the sum of incident solar energy for a certain area.

PRELIMINARY RESULTS

Gross Energy Values

Since measurements are available only for a two-year period, the results presented are of a preliminary nature.

Gross energy values of the plant material harvested are found in Table 2.

Efficiency of Net Primary Production

Utilization of solar energy by alpine pastures was calculated by degrees (Table 3). The results are arranged according to different management treatments and different original plant communities (Tables 3 and 4).

DISCUSSION

Gross Energy Values

Gross energy values of the samples taken show little difference as to management treatments, plant communities and years. Usually the samples of the first cutting are richer in energy, and the plant community *Seslerio-Caricetum sempervirentis* appears to have higher gross energy values than the other communities.

There seems to be no influence of fertilization on the energy content of the samples. The values are generally lower than those Runge got at the

TABLE 2. Gross energy values of the samples taken for different managements, plant communities and years, calories per gram dry matter

Variant	*Crepido-Cynosuretum*		*Carlino-Caricetum sempervirentis*		*Seslerio-Caricetum sempervirentis*		Average	
	First Cutting	Second Cutting	First Cutting	Second Cutting	First Cutting	Second Cutting	First Cutting	Second Cutting
				1974				
NPK	4 338	4 328	4 328	4 351	4 488	4 264	4 385	4 314
PK	4 282	4 365	4 275	4 313	4 405	4 416	4 321	4 365
O	4 333	4 320	4 409	4 190	4 382	4 418	4 375	4 310
Average	4 318	4 338	4 337	4 285	4 425	4 366	4 360	4 330
				1975				
NPK	4 356	4 348	4 398	4 230	4 381	4 401	4 378	4 326
PK	4 325	4 189	4 294	4 069	4 504	4 125	4 374	4 127
0	4 327	—	4 254	—	4 292	—	4 291	—
Average	4 336	4 268	4 315	4 149	4 392	4 263	4 338	4 227

TABLE 3. Efficiency of net primary production[a] of differently managed pastures in 1974 and 1975

Treatment	1974 First Cutting	1974 Second Cutting	1974 Average	1975 First Cutting	1975 Second Cutting	1975 Average	Average 1974/1975
NPK	0.86	0.87	0.865	1.11	0.76	0.94	0.90
PK	1.27	0.75	1.01	1.13	0.64	0.885	0.94
O	0.90	0.63	0.765	0.91	[illegible]	0.455	0.61
Average	1.01	0.75	0.88	1.05	0.45	0.758	0.819

[a]Energy content of harvested phytomass divided by sum of incident solar energy.

TABLE 4. Efficiency of net primary production[a] for different plant communities in 1974 and 1975

Plants	1974 First Cutting	1974 Second Cutting	1974 Average	1975 First Cutting	1975 Second Cutting	1975 Average	Average 1974/1975
Crepido-Cynosuretum	0.93	0.64	0.785	0.99	0.51	0.750	0.767
Carlino-Caricetum sempervirentis	0.75	0.60	0.675	0.98	0.35	0.665	0.670
Seslerio-Caricetum sempervirentis	1.24	0.97	1.105	1.12	0.48	0.800	0.907

[a]Energy content of harvested phytomass divided by sum of incident solar energy.

German Solling project in 1973 (at an elevation of 460 m). Runge found a gross energy of 4 410 calories for unfertilized, 4 350 for PK-fertilized and 4 426 for NPK-fertilized meadow hay. The reason for this discrepancy is the high ash content in the fodder of alpine pastures. The gross energy of the ash-free dry matter was calculated for a few samples and found to be much higher than the gross energy values of the Solling project ash-free dry matter (Table 5).

TABLE 5. Gross energy values for ash-free dry matter, calories/g

Treatment	1975 Average First Cutting	1975 Average Second Cutting
NPK	4 809	4 747
PK	4 807	4 723
O	4 771	4 753

Efficiency of Net Primary Production

There are differences in efficiency between management treatments, cuts and original plant communities. From the beginning of the vegetation period up to the first cutting, about 1% of solar energy was utilized. The PK-fertilized pasture appeared to be most efficient. An additional dose of N after the first cutting considerably improved the net primary production between the first and second cuttings. While the production of the unfertilized paddock was satisfactory during the first growth, it dropped after the first cutting and in 1975 no second cutting could be harvested from the O fertilizer level paddock (treatment variant 3).

Compared with results from the literature, the photosynthesis of the alpine pasture investigated is relatively efficient. During the German IBP program at the Solling project, the productivity of a Golden Oat meadow at 460 m above sea level was investigated (Speidel, Weib 1971, 1972; Runge 1973b). The efficiency of net primary production was 0.52% for the unfertilized meadow, 0.62% for the PK-fertilized one, and 0.90% for the NPK-fertilized one, during the vegetative period.

It must be considered, of course, that the vegetative period is rather short at high altitudes. Therefore, the yearly productivity remains small in spite of the efficient photosynthesis.

ACKNOWLEDGMENTS

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DISCUSSION

K. O'Connor (New Zealand). Could you give us some indications of your total standing crop or of your actual primary production per square m in weight? What you ha given us are results in caloric value.

Spatz. I can give you the approximate dry matter yield. This varies with the utilization of radiant energy, of course. They are very closely correlated, so the yield for the PK-fertilized paddock was about 6 tons per ha annually, almost half as much for the unfertilized.

E. deVries (Pennsylvania, USA). Did you change the grazing pattern of the animals?

Spatz. No. We used paddocks. Before the paddocks were grazed, we cut several of the parcels—12 parcels per paddock. The cattle came in and grazed everything and then they went out. The pastures got a rest, and before the second cutting we again cut 12 parcels. After this, the cattle came in again. We can assume the cattle have eaten as much as we have harvested. They cannot eat everything, there's always a residue, but they can come close to eating everything.

O'Connor. You were doing this out in a 3-paddock rotation. Is that what you meant to do it in?

Spatz. No.

O'Connor. Your NPK treatment, for example, is your most intensive. How long were the animals away each time?

Spatz. We had a herd of 50 animals—quite a lot. We took the herd and put some into the NPK paddock and they stayed there 3 or 4 days, not longer. Then we took them out again. After that we put them into the PK paddock, and then in the not-fertilized paddock, and then they came out from the trial until the next rotation. So, it was quite a long rest and a short grazing period. It's a very high stocking rate.

E. deVries. Did you find any correlation, for instance, with leaf surface capturing the radiation from that in any area more fully covered? Do you have higher efficiency in radiation? Did you try to measure the leaf surface?

Spatz. No. We haven't measured it yet. We haven't measured the leaf surface; we only measured the dry matter.

103.
Carbohydrate Content and Quality in Plants Depending on Climate Conditions in the Northern Alpine Area

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Vegetation used for cattle in the northern alpine area extends up to altitudes for more than 1 000 m above sea level. In spite of low yields and small capital and labor input, compared to lowland areas, surprisingly good animal productivity quite often is obtained. Farmers attribute this to major portions of herbs in the stand. The well-known conditions for optimal photosynthesis (Richter, 1969; Levin and Bidwell, 1974), however, and experiments in growth chambers with controlled temperature and radiation (Deinum, 1966; Smith, 1968) as well as investigations at field stations (Archibald, 1961; Farries, 1968; Lang *et al.*, 1972), suggest that climate conditions favoring synthesis and storage of large amounts of highly digestible carbohydrates in the plants are the main reason for this fact, instead of specially active substances in herbs.

This paper will try to demonstrate a quantitative connection between contents of nonstructural carbohydrates in forage plants and different altitudes and corresponding climate conditions in southern Bavaria.

Field Station Grünschwaige (435 m, near Weihenstephan)

At Grünschwaige, pasture plots were fertilized with four different levels of N from 1969 to 1970. Cuts were made at two different heights (30 and 45 cm) in May, July and August and contents of soluble carbohydrates were analyzed as described by Lang *et al.* (1972). The stand consisted of up to 92% grasses (24% *Poa pratensis*, 20% *Festuca pratensis*, 16% *Dactylis glomerata*, 15% *Agropyron repens*, 10% *Agrostis stolonifera*, 2% each of *Poa trivialis*, *Phleum pratense*, *Lolium perenne*, 1% *Alopecurus pratensis*). Carbohydrate contents were correlated by regression analysis with climate data and N-fertilization.

Field Stations on Altitude Gradients of 465 m, 705 m, 975 m, 1 450 m

In order to investigate the effect of an altitude gradient, vegetation trials with potted plants were conducted at Weihenstephan (465 m), Kempten (705 m), Hohen-Peißenberg (975 m) and Sandbichler-Alm (1 450 m) (Fig. 1). Each site was located close to regular stations of the Deutscher Wetterdienst, or stations were specially equipped for that particular purpose. The meteorological data used were total (= sum of) temperature above 5 C, average temperature > 5C, average minimum temperature and total radiation (cal/cm^2) two and five days before harvest. Meteorological data were provided by the Deutscher Wetterdienst. (The author thanks in particular Prof. Dr. van Eimern, Dr. W. Attmanspacher and Dr. H. Häckel.)

Seeds of *D. glomerata*, *F. rubra*, *Trifolium repens* and *Anthyllis vulneraria*, as well as seedlings of *Taraxacum officinale* and *Plantago lanceolata*, were planted in plastic pots (17 × 17 × 17 cm) filled with loamy soil (7 mg K_2O/100 g soil, 8 mg P_2O_5/100 g soil, pH 7.4). Four pots of each plant species were transported to each of the four locations and placed 15 cm deep in the original sod.

Over the growth period, *T. officinale* and *P. lanceolata* were harvested several times at vegetative stage and at flowering. Grasses remained vegetative at all sites because of the lack of vernalization. At Weihenstephan and Kempten, of the legumes only *Trifolium repens* flowered, whereas at Hohen-Peißenberg and Sandbichler-Alm it died out completely because of the unusual drought in 1976. *A. vulneraria* grew very slowly at Sandbichler-Alm, and only one harvest could be made.

To avoid diurnal variation in carbohydrate contents, plants were harvested at 9 and 10 a.m. This was followed immediately by adding ice to plant samples in order to reduce enzymatic reactions during the transport of the material to the laboratory. Samples were stored at −20 C and finally freeze dried.

Dried plant material was ground (< 1 mm) and extracted 1 hr with 95% EtOH followed by 1 hr extractions with 85% EtOH and water, successively, in order to dissolve mono- and disaccharides, both in 95% and 85% EtOH, and fructosan plus water soluble amylose, eventually, both in water extracts (Kühbauch, 1973; Smith, 1975).

Starch extracts were prepared by shaking the residues of the above sugar extraction with 1.1% HCl. Starch in the filtrate was estimated enzymatically by means of amyloglucosidase, hexokinase + ATP and glucose-6-phosphate-dehydrogenase + NADP according to Boehringer (1971).

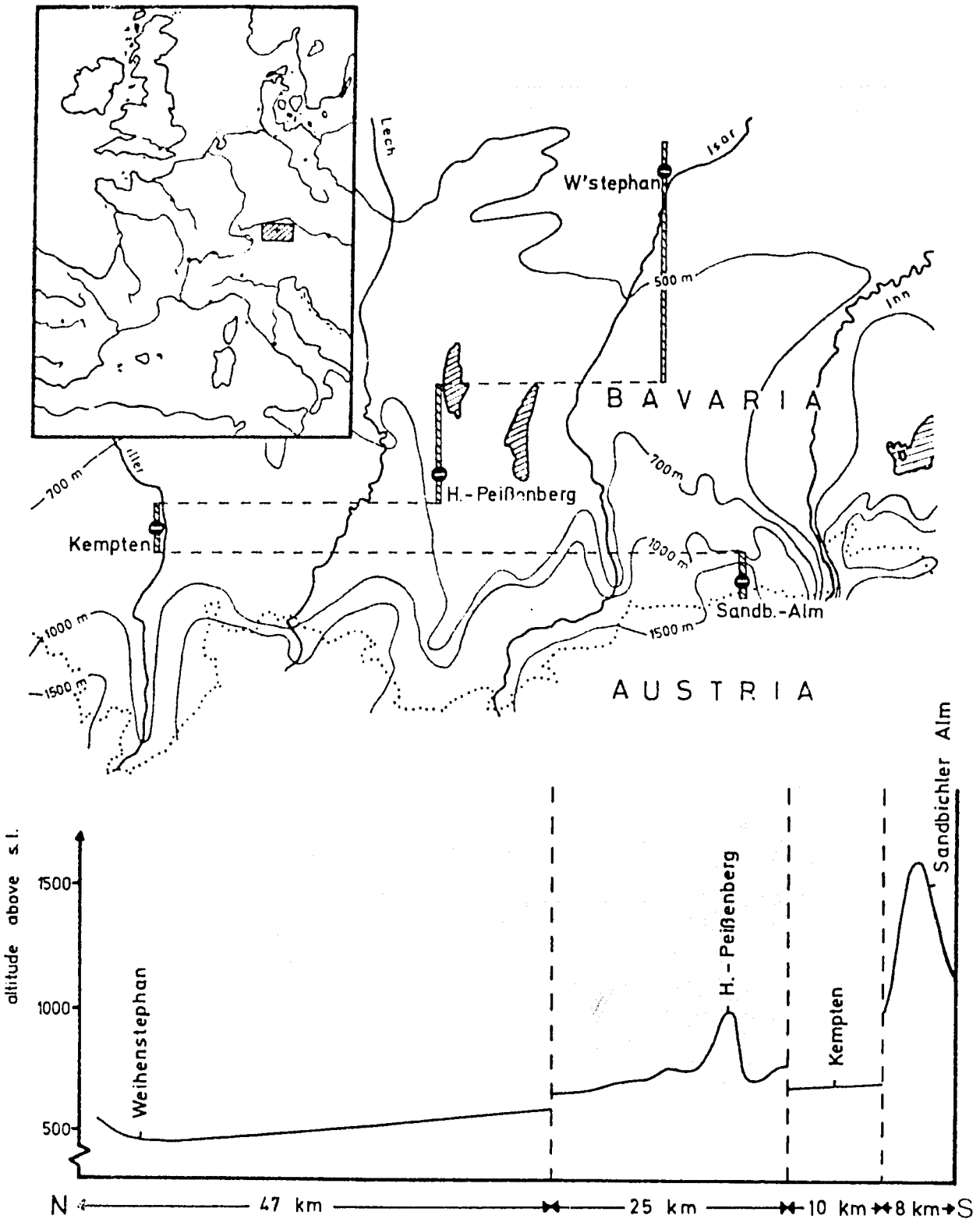

Figure 1. Geographical sites and positions above sea level of field stations on an altitude gradient.

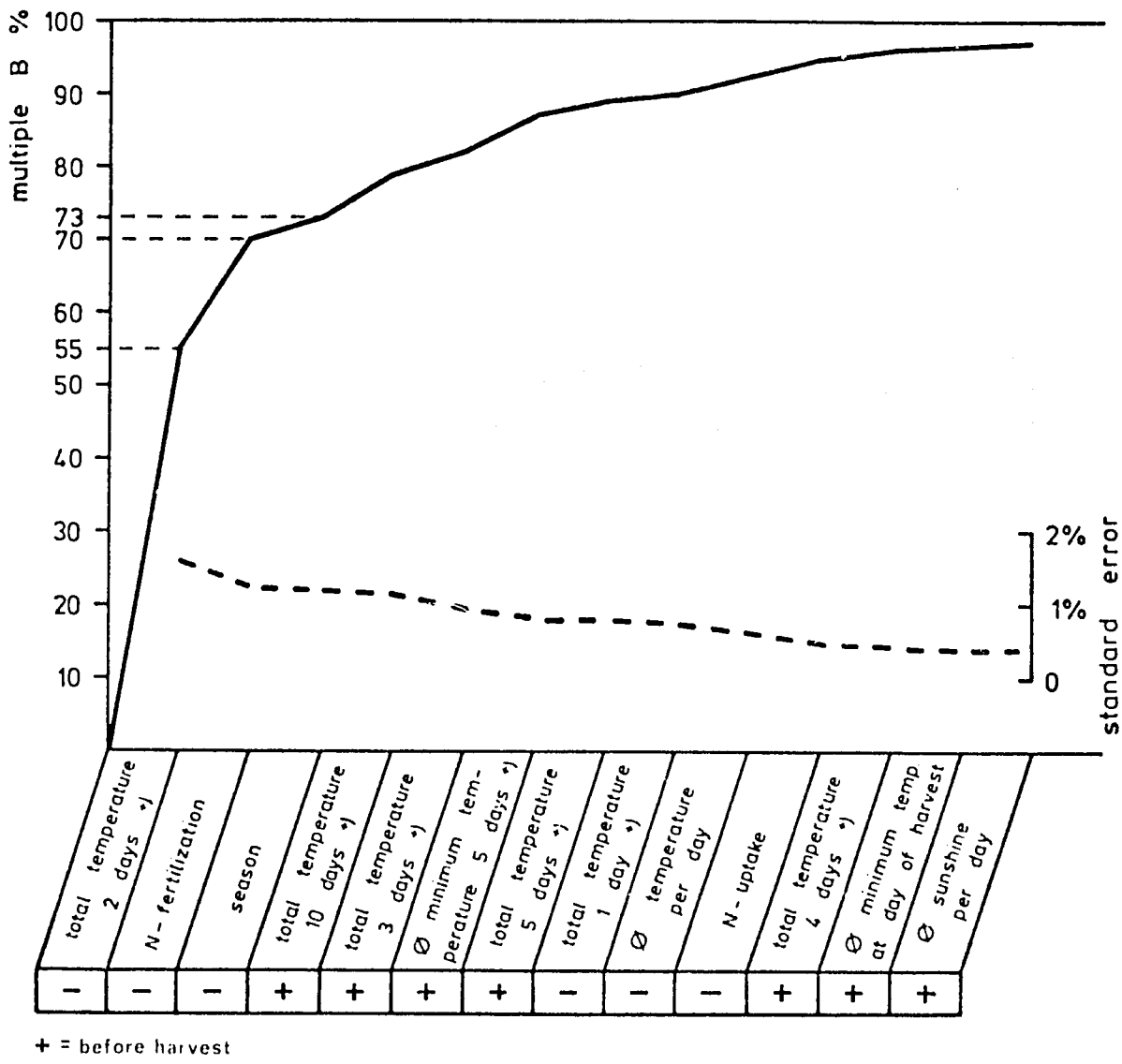

Figure 2. Sign and contribution to the multiple B of the variables that serve to explain the variance in the contents of soluble carbohydrates. Value and alteration in the standard deviation of the estimation (n = 48).

RESULTS AND DISCUSSION

Field Station Grünschwaige (435 m)

Fig. 2 shows the regression of various influences on contents of soluble carbohydrates in the above described pasture plants (field station Grünschwaige). With the program used (BMDO2R), the multiple linear equation is continued stepwise (Dixon, 1973). Selection of influencing variables was performed according to F-test. At first, a partial correlation was calculated between each of the variable factors and the target (soluble carbohydrates). Variables with highest F-value were put into the equation successively. Selection of variables stopped if there were no more variables available, reaching a given F-value of 1.0. In Fig. 2 on the abscissa the influence factors are given in the order of importance, on the ordinate the increasing multiple B is given (= multiple $r^2 \times 100$).

Using 13 variables, up to 97% of the variance of soluble carbohydrates can be explained, the most important influence being total temperature two days before harvest (negatively correlated). With this factor, 55% of the total variability of soluble carbohydrate contents can be explained. N-fertilization adds 15% more of explanation and season another 3% (both negatively correlated). The next three variables add another 5% (positively correlated), while the influence of the rest of the variables decreases. It is noteworthy that the influence of management on carbohydrate contents out of the computerized variance of 97% was 15% (N-fertilization) only. The

influence of harvest date on carbohydrate contents was small, probably because it was covered by climate parameters. Moreover, plants were harvested at both heights in the vegetative stage.

Fig. 3 shows the relationship between contents of soluble carbohydrates and total temperature, N-fertilization being 60 kg N/ha. It shows the extent of temperature influence; sugar content in forage plants decreased drastically with increasing temperature. Results shown in Figs. 2 and 3, however, cannot be generalized. Outputs of regression analyses are valid only for conditions of the corresponding experiment. Theoretically, however, it should be possible to use simple climate data for rough estimation and prediction of carbohydrate contents, respectively.

Field Stations on Altitude Gradients of 465 m, 705 m, 975 m, 1 450 m

The data shown above are consistent with results from growth chamber research as far as temperature influence is concerned (Smith, 1968). It suggests that in the alpine area, sugar contents in plants increase in general with altitude. In addition, this idea is supported by findings that increase in radiation yields higher sugar contents in forage plants (Deinum, 1966).

The legumes *T. repens* and *A. vulneraria* contain mono- and disaccharides and starch, the latter in some cases in appreciable amounts. The herbs *P. lanceolata* and *T. officinale* contain mono- and disaccharides and smaller amounts of starch (Fig. 4).

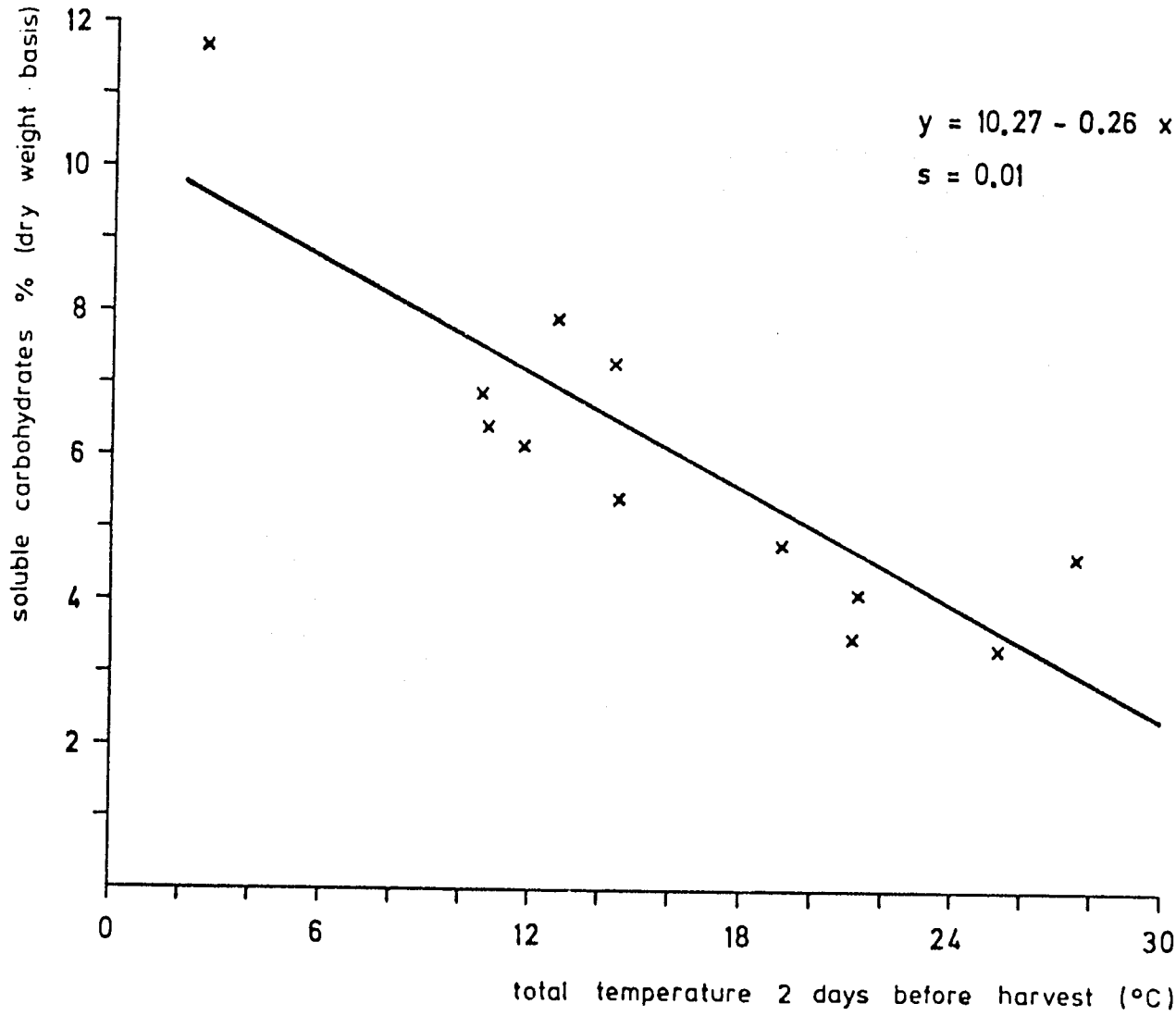

Figure 3. Relationship between the content of soluble carbohydrates and the sum of temperatures two days before harvest with N fertilization of 60 kg N/ha and cut (n = 12).

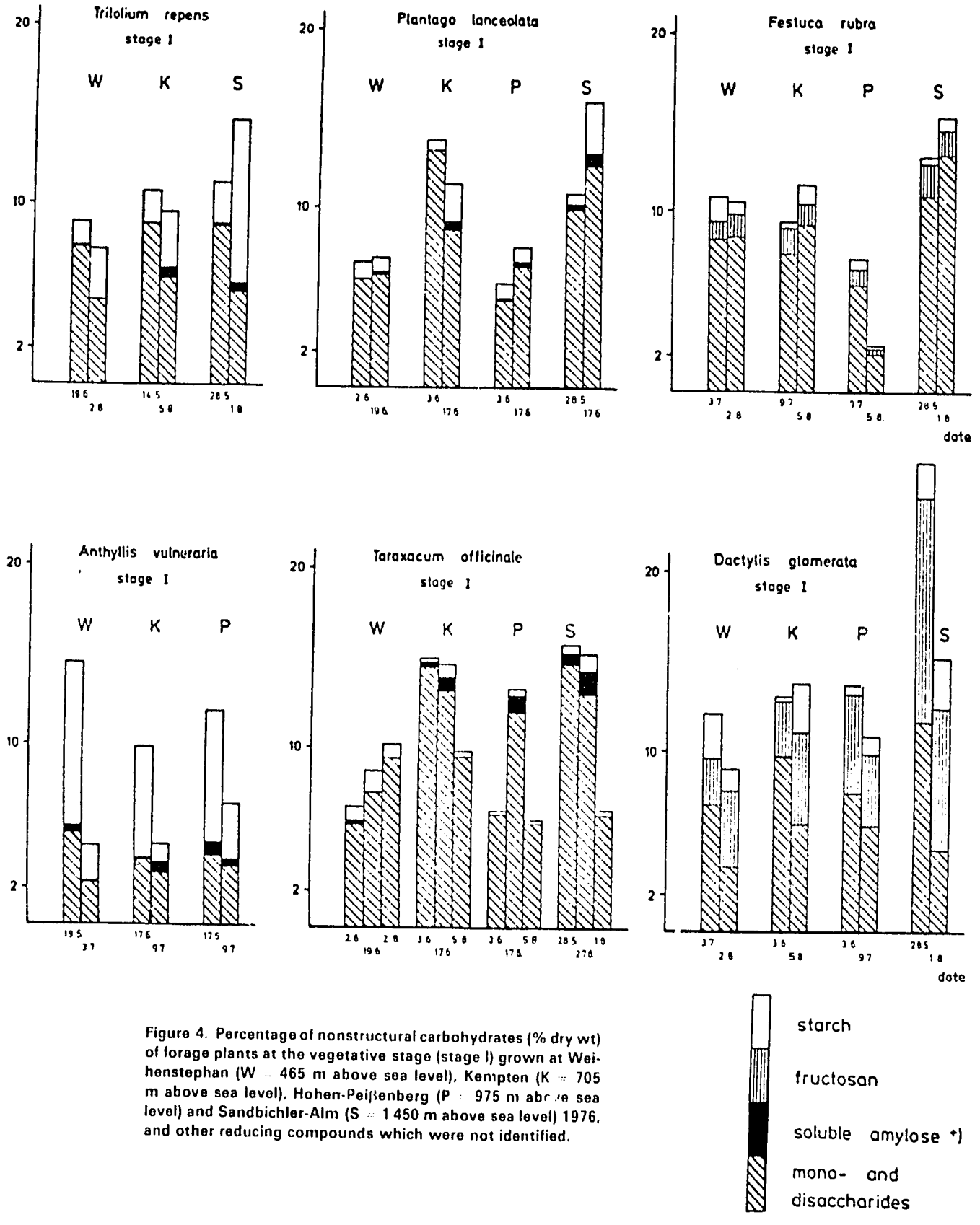

Figure 4. Percentage of nonstructural carbohydrates (% dry wt) of forage plants at the vegetative stage (stage I) grown at Weihenstephan (W = 465 m above sea level), Kempten (K = 705 m above sea level), Hohen-Peißenberg (P = 975 m above sea level) and Sandbichler-Alm (S = 1 450 m above sea level) 1976, and other reducing compounds which were not identified.

In addition, *F. rubra* and especially *D. glomerata* synthesized large amounts of fructosans. Highest carbohydrate concentrations were always found at Sandbichler-Alm in *T. repens* at one harvest date and in *D. glomerata* at both harvest dates predominantly consisting of polymer carbohydrates, such as starch or fructosans. At all locations, the variation of carbohydrate contents within the same species is very high, even though in all cases plants were harvested at vegetative stage of growth. As shown below, the reason is a considerable influence of climate factors.

We started with the idea that with increasing altitude, equivalent to low day and night temperatures and higher radiation, respectively, the sugar content in all plants should increase. Locations at Weihenstephan, Kempten and Sandbichler-Alm with all species (except *A. vulneraria*) so far show roughly the expected trend (Fig. 5). At location Hohen-Peißenberg unexpected small amounts of sugars were stored in the plants. The regression line, however, was much affected by *D. glomerata* at high altitudes.

With the correlation r = 0.50, a relationship between altitude and sugar content results, which is not too close. In fact, a causal explanation of carbohydrate contents simply by altitude, without climate conditions taken into account, might be inadmissible.

The real reason for differences in sugar contents at the four locations turned out to be differences in temperature, as shown in Fig. 6 (upper part) with the example of average temperature above 5 C five days before harvest. Weihenstephan is the warmest place—three out of four harvest periods showed higher temperature compared to Kempten und

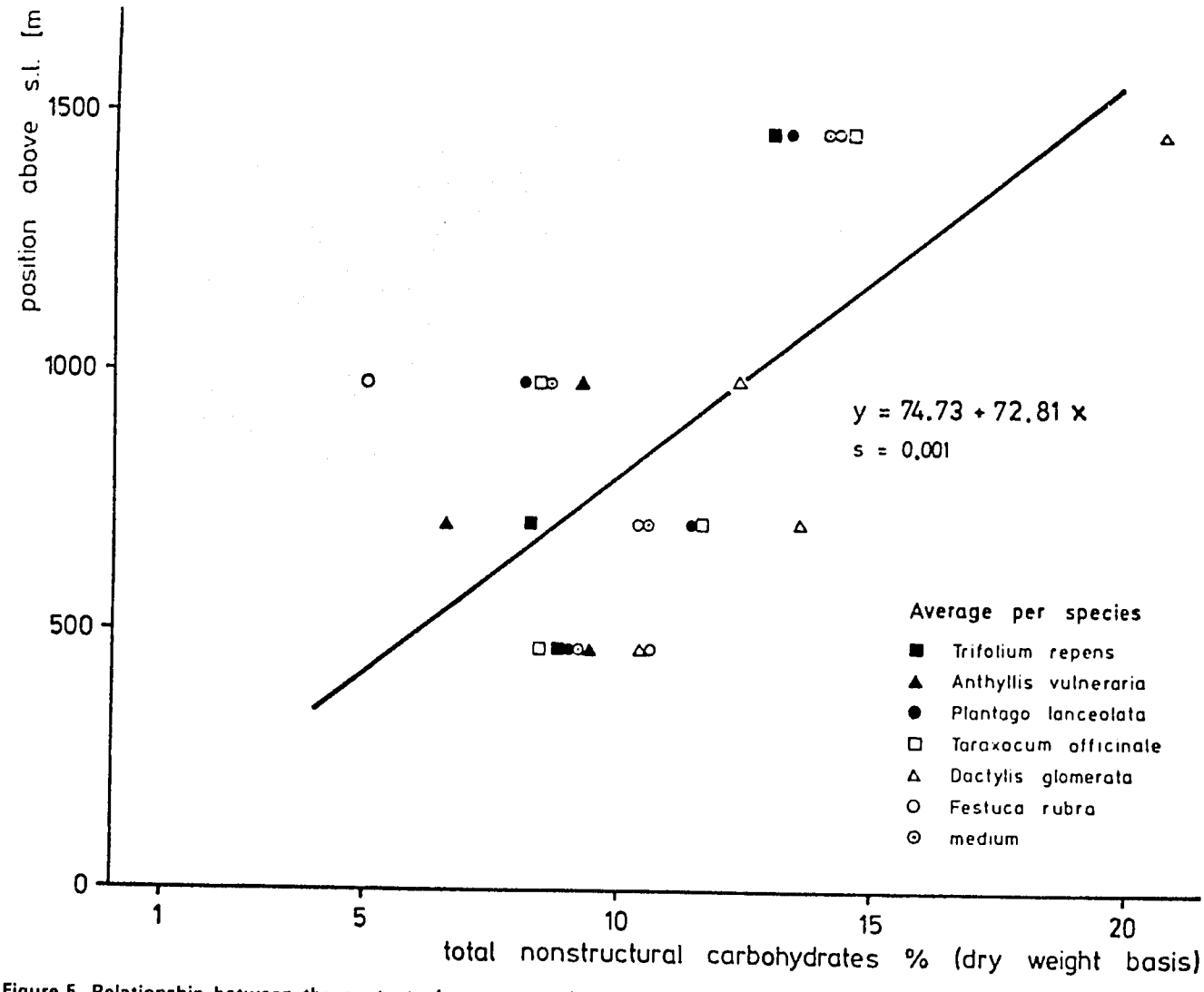

Figure 5. Relationship between the content of nonstructural carbohydrates and position above sea level for six plant species grown at different altitudes in the northern alpine area.

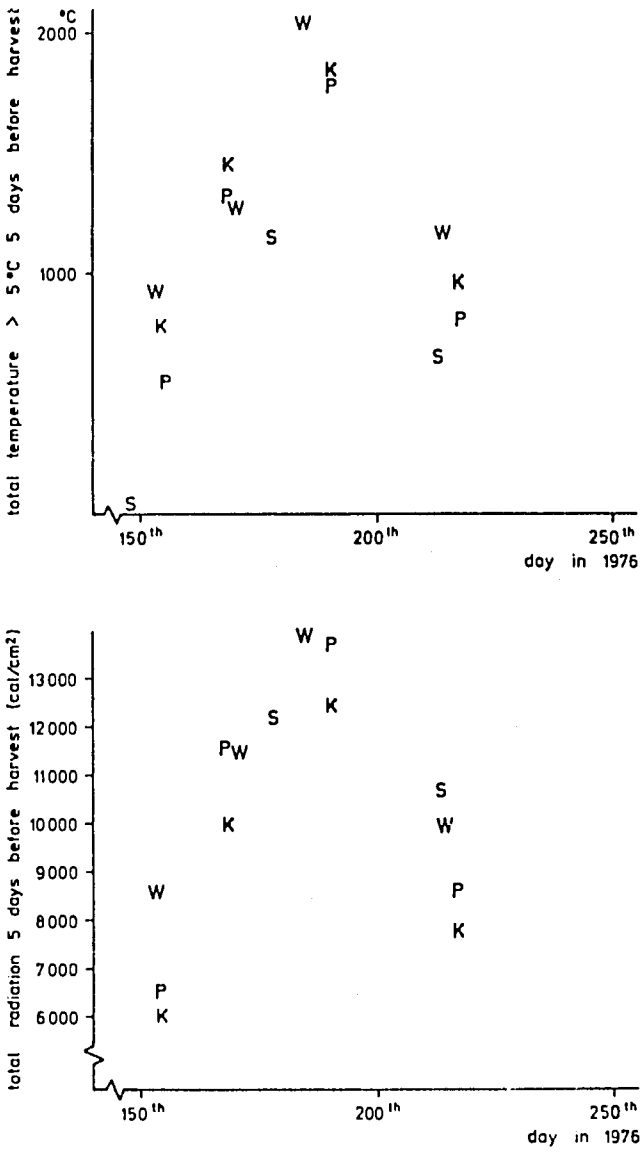

Figure 6. Total temperature above 5 C and total radiation five days before harvest at field stations in Weihenstephan (W), Kempten (K), Hohen-Peißenberg (P) and Sandbichler-Alm (S) 1976.

Hohen-Peißenberg. Locations at Sandbichler-Alm, however, show at corresponding harvest dates lowest temperatures with a clear difference to all other stations. Locations at Kempten and Hohen-Peißenberg are close together in temperature. Hence, it follows that Hohen-Peißenberg is warmer than expected for its altitude. It is a mountain that rises out of the surrounding lowland area so that with inversion weather conditions, downward movement of cold air is favored (Vollrath, 1976).

At Sandbichler-Alm (1 450 m) one time even lower radiation was measured compared to lowland areas at Weihenstephan (465 m) (Fig. 6). The other time Weihenstephan and Sandbichler-Alm were close together (radiation data at Sandbichler-Alm was not available before June). Probably the unusual long-lasting drought of this year (1976), together with small relative humidity, caused unexpected high radiation on the lowland. Radiation, however, had a subordinate influence on development of carbohydrates. The correlation of temperature above 5 C and nonstructural carbohydrates over all plant species and locations reached a value up to r = −0.5 (Fig. 7). Average temperature two days before harvest gave the highest correlation, followed by total temperature above 5 C, both correlations being negatively oriented and highly significant (s = 0.001). With these data, the overwhelming negative influence of higher temperatures on carbohydrate contents of plants is principally confirmed and, as far as physiology is concerned, the importance of dissimilation with plants of moderate climate areas.

In Table 1, the data of Fig. 7 are specified for the single plant species. For several plants, highly significant dependences up to r-values of −0.76** (for instance, *D. glomerata*) show that most important influences again are average and total temperatures above 5 C (see total nonstructural carbohydrates and mono- and disaccharides, both negatively correlated steadily). Only nonstructural carbohydrates of *A. vulneraria* show a close relation to average minimum temperature (r = −0.76**). Carbohydrate contents of *F. rubra* show no significant dependence from the climate parameters used.

The influence of radiation only with the herbs shows up sometimes important and significant (r = 0.54** and r = 0.77**, respectively).

In some instances, negative correlations were calculated for carbohydrate contents and radiation. These cases cannot be explained logically. It seems to be a kind of physiological nonsense which might be caused by an intercorrelation of temperature and radiation and the small volume of data available.

In conclusion, in spite of the small numbers of data which were computerized, the available data show quite clearly the negative influence of high temperatures on contents of nonstructural carbohydrates. The influence of radiation in 1976 turned out to be much lower in comparison to that. Hence, it follows as far as the northern alpine area is concerned, that roughly and with distinct deviations of single species, possibly depending on water conditions, with increase in altitude in some important plants, higher amounts of sugar are produced. This, in turn, means better quality forages.

It may be possible to describe different locations based on a kind of mapping for grassland areas using the potential to produce nonstructural carbohydrates in some representative plants.

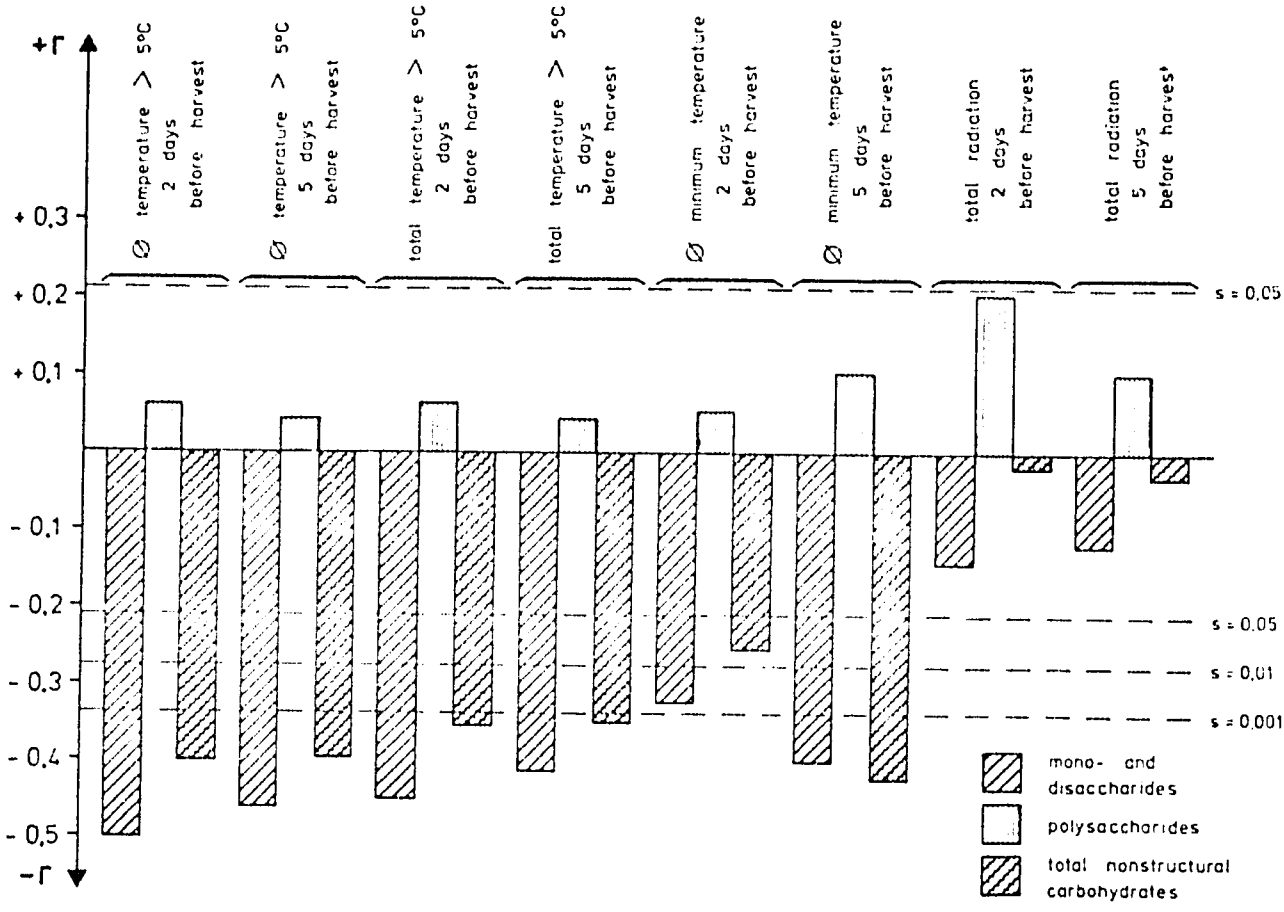

Figure 7. Correlation of temperature and radiation with nonstructural carbohydrates, average out of six plant species grown on an altitude gradient; n = 72 (species · cuts · locations), s = significance.

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DISCUSSION

E. deVries (Pennsylvania, USA). You harvested between 9 and 10 in the morning? The comparison in Java is that for cigarette tobacco that's supposed to be sweet, you must pick the leaf between 6 and 8 in the morning. For cigar tobacco, which is not to be sweet, you want to harvest between 2 and 4 in the afternoon. So it might be interesting in further experiments to compare the carbohydrates in your plants between morning and evening cuttings.

Voigtlander. Normally we can expect that the carbohydrate content is highest in the afternoon. We wanted to have equal dates for harvesting and, because of practical reasons, we have taken the harvest in the morning. The figure will normally be higher in the afternoon.

TABLE 1. Correlation of temperature and radiation with contents of nonstructural carbohydrates for each of six plant species grown on an altitude gradient (n = cuts + locations)

Nonstructural Carbohydrates	ϕ Temperature > 5 C Before Harvest		Total Temperature > 5 C Before Harvest		ϕ Minimum Temperature Before Harvest		Total Radiation Before Harvest	
	2 Days	5 Days	2 Days	5 Days	2 Days	5 Days	2 Days	5 Days
				Trifolium repens (n = 8)				
Mono- and disaccharides	−0.683[a]	−0.562	−0.527	−0.467	−0.496	−0.489	0.645	0.315
Polymers	0.206	0.047	0.175	0.024	0.341	0.349	0.135	−0.204
Total nonstructural carbohydrates	−0.180	−0.270	- 0.122	−0.239	0.060	0.072	0.371	−0.090
				Anthyllis vulneraria (n = 9)				
Mono- and disaccharides	−0.490	−0.371	−0.556	−0.408	−0.758[b]	−0.717[a]	−0.218	−0.226
Polymers	−0.403	−0.160	−0.417	−0.218	−0.552	−0.214	−0.065	−0.008
Total nonstructural carbohydrates	−0.514	−0.267	−0.550	−0.330	−0.736[a]	−0.437	−0.133	−0.088
				Plantago lanceolata (n = 21)				
Mono- and disaccharides	−0.218	−0.269	−0.183	−0.200	−0.047	−0.110	0.170	0.049
Polymers	0.483[a]	0.516[a]	0.482[a]	0.496[a]	0.224	0.398[a]	0.484[a]	0.535[b]
Total nonstructural carbohydrates	0.008	−0.026	0.042	0.031	0.055	0.074	0.372	0.283
				Taraxacum officinale (n = 17)				
Mono- and disaccharides	−0.610[b]	−0.570[b]	−0.570[b]	−0.523[a]	−0.393	−0.501[a]	0.225	−0.062
Polymers	0.104	0.130	0.192	0.209	0.171	0.211	0.641[b]	0.774[c]
Total nonstructural carbohydrates	−0.573[b]	−0.529[a]	−0.517[a]	−0.468[a]	−0.348	−0.446[a]	−0.060	0.122
				Dactylis glomerata (n = 9)				
Mono- and disaccharides	−0.515	−0.388	−0.392	−0.317	−0.394	−0.435	−0.332	−0.099
Polymers	−0.632[a]	−0.744[a]	−0.506	−0.663[a]	−0.300	−0.563	0.086	−0.313
Total nonstructural carbohydrates	−0.747[a]	−0.760[b]	−0.587[a]	−0.661[a]	−0.436	−0.653[a]	−0.271	−0.468
				Festuca rubra (n = 8)				
Mono- and disaccharides	−0.311	−0.345	−0.310	−0.334	−0.146	−0.113	−0.060	−0.275
Polymers	−0.080	−0.066	−0.035	−0.028	0.143	0.132	0.106	0.064
Total nonstructural carbohydrates	−0.280	−0.308	−0.273	−0.292	−0.103	−0.077	−0.034	−0.226

[a]s = 0.05
[b]s = 0.01
[c]s = 0.001
ϕ = average

K. O'Connor (New Zealand). We now see that this work has vindicated the judgment that the high altitude pastures are sweeter. That is almost a proverbial statement, and I hope that you will take that message to the author of this work. May I ask, was there any opportunity to examine the weather conditions in terms of cloudiness and that sort of thing associated with the lower temperatures, especially if this was possible for different samples from the same site? I agree with the case that has been made for the overall situation. I'm just hoping to understand further why it is that we get the soluble carbohydrate accumulation. I presume that the soluble carbohydrates are not being converted into structures and this is why we've got the soluble carbohydrate accumulation. I would like to know what actual kinds of weather conditions rather than the climatic parameter were associated with this phenomenon.

Voigtlander. You are right. I think that abnormal weather conditions can account for some variation. But if one leaves weather conditions and goes to the climatic, then I think we have very close relations. We thought a kind of mapping for grassland areas using the potential to produce nonstructural carbohydrates and some representative plants could be useful and could describe different locations. But it is for the future, I think.

104.
Intensive Rearing Systems for Sheep Production

L. Ainsworth, A. J. Hackett, D. P. Heaney, G. A. Langford, H. F. Peters, and J.N.B. Shrestha
Animal Research Institute, Ottawa, Ontario, Canada

Sheep are well adapted to hill land agriculture and, over the years, attempts have been made to identify the factors limiting sheep productivity from the hill (Alcock, 1975; Lucas, 1975). It is considered that the major constraint to increased animal production is insufficient feed, and it is evident from the papers presented at this symposium that considerable research effort is being expended to increase and improve the forage production potential from marginal and hill land areas. In spite of these developments, the fact remains that in most agriculturally productive countries, ewes are seasonal breeders and often produce lamb crops below the potential fecundity for the particular breed. Although ample scope exists for improving the breeding performance of the ewe and efficiency of lamb production by modifying traditional methods of breeding, nutrition and management of the flock, the sheep industry, in general, is far from achieving its optimum in reproductive output (Bindon, 1974).

Over the past decade, significant advances have been made in increasing the reproductive output of sheep flocks through application of controlled breeding techniques. These techniques were developed following the reports by Australian workers (Robinson, 1964, 1965) that the estrous cycle of the sheep could be controlled by the use of intravaginal polyurethane pessaries impregnated with progestagens.

This presentation will review the advances made in the development and application of controlled breeding techniques using data generated from research programs established in Eire and France. In addition, attention will be devoted to the application of controlled breeding techniques in experimental total confinement programs which have been established at the Rowett Research Institute, Aberdeen, Scotland and the Animal Research Institute, Ottawa, Canada.

DEVELOPMENT OF CONTROLLED BREEDING TECHNIQUES USING INTRAVAGINAL PESSARIES IMPREGNATED WITH PROGESTAGEN

Type of Progestagen Used in Intravaginal Pessaries

Although a number of progestational agents are available, few are considered appropriate for use in control of sheep breeding. Screening of various progestational agents by Australian workers (Shelton *et al.*, 1967; Shelton and Robinson, 1967) established that only compounds with physiological characteristics similar to progesterone, particularly the short biological half-life, were suitable. Of the compounds tested, fluorogestone acetate (FGA),* which has a potency 25 times greater than progesterone in the inhibition of ovulation (Shelton, 1965), has been used extensively. Sponge pessaries impregnated with 30 mg or 40 mg FGA are available commercially (G. D. Searle) and provide the most widely used intravaginal treatment for controlled breeding of sheep.

Use of Pregnant Mares' Serum Gonadotropin (PMSG)

Quinlivan and Robinson (1967, 1969) have demonstrated that progestagens decrease the survival and impede transport of spermatozoa in the genital tract of the ewe, resulting in a lowered fertility at the synchronized or induced estrus. This lowered fertility can be largely overcome by injection of a low dose of PMSG at the time of sponge withdrawal. Injection of PMSG induces a mild superovulatory effect resulting in an increase in prolificacy, an advancement of the onset of estrus and a more precise and reliable synchronization of ovulation (Gordon, 1971; Cognie *et al.*, 1968, 1970; Colas, 1975b). The use of PMSG in conjunction with the intravaginal treatment is mandatory during the anestrous season if an acceptable estrous response and conception rate are to be obtained (Gordon and Keane, 1967; Thimonier *et al.*, 1968a). During the normal breeding season, the use of PMSG increases the level of fertility at the induced estrus (Colas *et al.*, 1973).

Procedures for Controlled Breeding of Sheep

The technique developed by Gordon and associates (Gordon, 1975a,b) at University College, Dublin, in which ewes are bred by natural service, involves treatment with intravaginal sponges impregnated with 30 mg FGA for two weeks, dusting of sponges with an antibiotic powder at insertion and an intramuscular injection of PMSG (usually 500 IU) at sponge withdrawal. Sexually experienced rams are introduced (1:10 ratio) 48 hr after termination of treatment and remain with the ewes for at least three

*9α-fluoro-11β-hydroxy-17α-acetoxy-pregn-4-ene-3,20-dione; SC-9880; G. D. Searle.

TABLE 1. Hormonal treatments used for the induction and synchronization of the estrous cycle in sheep (from Thimonier and Cognie, 1971)

Physiological State of Ewes	Breeding Season: Dose of FGA (mg)	Breeding Season: Duration of Treatment (days)	Breeding Season: Dose of PMSG (IU)[a]	Anestrous Season: Dose of FGA (mg)	Anestrous Season: Duration of Treatment (days)	Anestrous Season: Dose of PMSG (IU)[a]
Dry ewes	30 or 40	14	400	30 or 40	12 or 14	400-800
Lactating ewes	30 or 40	12	400-600	30 or 40	12	500-800
Ewe lambs (7-8 months)	40	14	250-400	40	14	400-600

[a]PMSG is injected intramuscularly at the time of sponge removal. The overall treatments vary with the time of the year, the breed and the physiological state of the ewe.

weeks. The ewes are run at grass in groups not exceeding fifty.

In France, the treatment schedule is similar except that the dose of FGA used and the duration of treatment depends upon the physiological state of the female and the season (Table 1).

It should be emphasized that for the treatments to be effective, they need to be applied under adequate animal husbandry and management conditions. Particular emphasis is placed on the nutritional condition of males and females and the minimization of stressful situations during and after treatment.

APPLICATION OF CONTROLLED BREEDING TECHNIQUES

Since the middle 1960's, research programs based on the use of the intravaginal sponge impregnated with FGA have been actively pursued by workers at University College, Dublin, Eire, and at the Station de Physiologie de la Reproduction, Centre de Tours, I.N.R.A., Nouzilly, France. In both of these programs, the major emphasis has been on attention to detail and establishment of extensive field testing programs under supervision. This approach has allowed the gradual solution of problems and given rise to an effective and simple method for control of the breeding activity of sheep.

The technique has been applied under a range of breed and management conditions, at all seasons of the year and among sheep in all different physiological states (Table 2). The technique is now in widespread commercial use in both countries, the service being provided to sheep farmers through cattle artificial insemination centers.

Although little has been done to date to apply controlled breeding techniques to commercial hill land production situations, it is conceivable that these techniques can be applied to economic advantage under the appropriate seasonal, nutritional and husbandry conditions. Gordon (1973) has stated that hill sheep (Blackface Mountain × Cheviot) respond as readily as lowland sheep to the FGA impregnated sponge + PMSG technique.

TABLE 2. Ways in which intravaginal sponge pessaries impregnated with FGA followed by PMSG are being applied to control the breeding activity and increase the reproductive output of sheep

Sheep Category or System	Reference
1. Breeding ewe lambs	Thimonier *et al.*, 1968b; Keane, 1974
2. Breeding of dry mature ewes in late anestrus for early lamb production	Gordon, 1975a, b
3. Breeding of ewes in lactational anestrus	Thimonier *et al.*, 1968a; Cognie *et al.*, 1975
4. Induction or synchronization of estrus followed by set-time AI using fresh or frozen semen	Gordon, 1975a, b, 1976; Colas, 1975a, b
5. Increasing litter size	Gordon, 1975a, b; Theriez *et al.*, 1971
6. Intensification of management, increasing lambing frequency, continuous year-round production	Cognie and Colas, 1968; Thimonier and Cognie, 1971; Thimonier *et al.*, 1975

CONTROLLED INTENSIVE BREEDING AND REARING SYSTEMS FOR SHEEP PRODUCTION

France

The French have done more than any other group to exploit the use of modern technology to intensify and to increase the efficiency and productivity of commercial lamb production. The production schemes which have been devised are based on the use of a combination of modern management techniques.

A. **Synchronization or induction of estrus and ovulation** with FGA-impregnated intravaginal sponges followed by intra-muscular injection of PMSG at sponge removal, according to the procedures outlined in Table 1.

B. **Fixed-time AI, without detection of estrus, with either fresh or frozen spermatozoa** (Colas, 1975b). By combining the above techniques, it is possible to obtain high fertility throughout the year in dry adult ewes, in ewe lambs at 6–8 months of age, provided they have reached at least 60% of adult weight, and in lactating ewes at 40–50 days after parturition.

C. **Early pregnancy diagnosis by estimation of the peripheral plasma progesterone levels at 18 days after breeding** (Robertson and Sarda, 1971; Saumande and Thimonier, 1972). By use of this technique ewes that are not pregnant can be scheduled for retreatment.

D. **Induction of parturition by administration of dexamethasone** (Bosc, 1973). A single intra-muscular injection of 10–15 mg dexamethasone at 143–144 days of pregnancy results in 90–95% of pregnant ewes lambing over a 48-hour period. If the dexamethasone is administered in the evening, approximately 70% of the treated animals will lamb during the second day following treatment between 6:00 A.M. and 6:00 P.M. Induction of parturition reduces the lambing period and facilitates supervision, resulting in a reduction of perinatal mortality.

E. **Artificial rearing and weaning of lambs on milk replacer.** It has been established that the fertility of lactating ewes increases with the interval from parturition to breeding and decreases with the number of lambs suckled (Cognie *et al.*, 1975). The level of fertility also is decreased whatever the time interval when the ewes are bred in the spring rather than in the autumn. These authors also have shown that the level of fertility can be improved significantly if lactation is suppressed by removal of lambs at 12–24 hr after birth and the ewes are bred at 50–58 days after parturition.

Some or all of the above techniques have been integrated into several schemes of flock management which have been tested experimentally and are now being used commercially in one form or another on an increasing scale (Thimonier and Cognie, 1971; Thimonier *et al.*, 1975). Using such schemes, there is a 60–100% increase in numerical productivity, including early reproduction of ewe lambs, compared to traditional breeding methods. The French have also introduced the highly prolific Russian Romanov and Finnish Landrace breeds into their breeding programs, and extensive testing of crosses of these breeds with the traditional French breeds is being carried out.

Rowett Research Institute, Aberdeen, Scotland

A detailed description of this program, which was initiated in October, 1971, has been given by Robinson (1974). The unit is highly intensive and involves year-round confinement on zero grazing in a light-controlled environment. Two groups each of 48 unselected Finnish Landrace × Dorset Horn ewes have been bred to Suffolk rams every 205 days to produce lambs which are abruptly weaned at four weeks of age on to cereal-based diets. The system combines photoperiodism using the principles demonstrated by Yeates (1949) and polyurethane intravaginal sponge pessaries impregnated with 30 mg FGA plus 400 mg progesterone, as described by Gordon (1971), for the induction and synchronization of estrus, respectively. The photoperiod treatment consists of a natural daylength pattern together with an artificial pattern as illustrated in Fig. 1. The pattern is similar for each group of ewes but with a displacement of 102 days. Following the abrupt increase in light duration to 18 hr at 60 days after the synchronized estrus and the maintenance of this level to 90 days, the light is gradually decreased at the rate of 3.5 min per day. Thus, irrespective of the time of the year at which the ewes lamb, they are always mated at a daylength equivalent to that of October under natural conditions. Ewes are hand mated at the synchronized estrus to Suffolk rams using a procedure similar to that described by Jennings and Crowley (1970). Ewes that do not conceive are exposed to rams again twice daily during the period 15–21 days after the synchronized estrus. The number of lambs carried by the ewe is assessed by X-ray diagnosis at 12 weeks of pregnancy (Wenham and Robinson, 1972) and the feeding regime adjusted according to the number of fetuses. Superimposed on this general scheme are nutritional regimes designed to determine the capacity of the ewe to withstand the pressure of continual pregnancy and lactation. Over a period of five consecutive reproductive cycles, a total of 843 lambs were produced from the original 96 ewes. A total of 89 ewes, or 93%, conceived at 3 or more of the possible 5 cycles and produced an average of 3.4 lambs per ewe per year (Robinson *et al.*, 1975). While this scheme demands a high input, the output is also high and it is believed that this type of production system is economically feasible with experienced management.

Animal Research Institute (ARI), Ottawa, Canada

The rationale for, and a general description of the facilities and experimental approach used in the total confinement sheep production research program established at ARI has been presented (Gowe *et al.*, 1974). This program was conceived as a "systems approach" in which expertise from various disciplines would be utilized and integrated into a research program, the objective of which is to develop an intensive sheep production system adaptable to Canadian conditions. The way in which

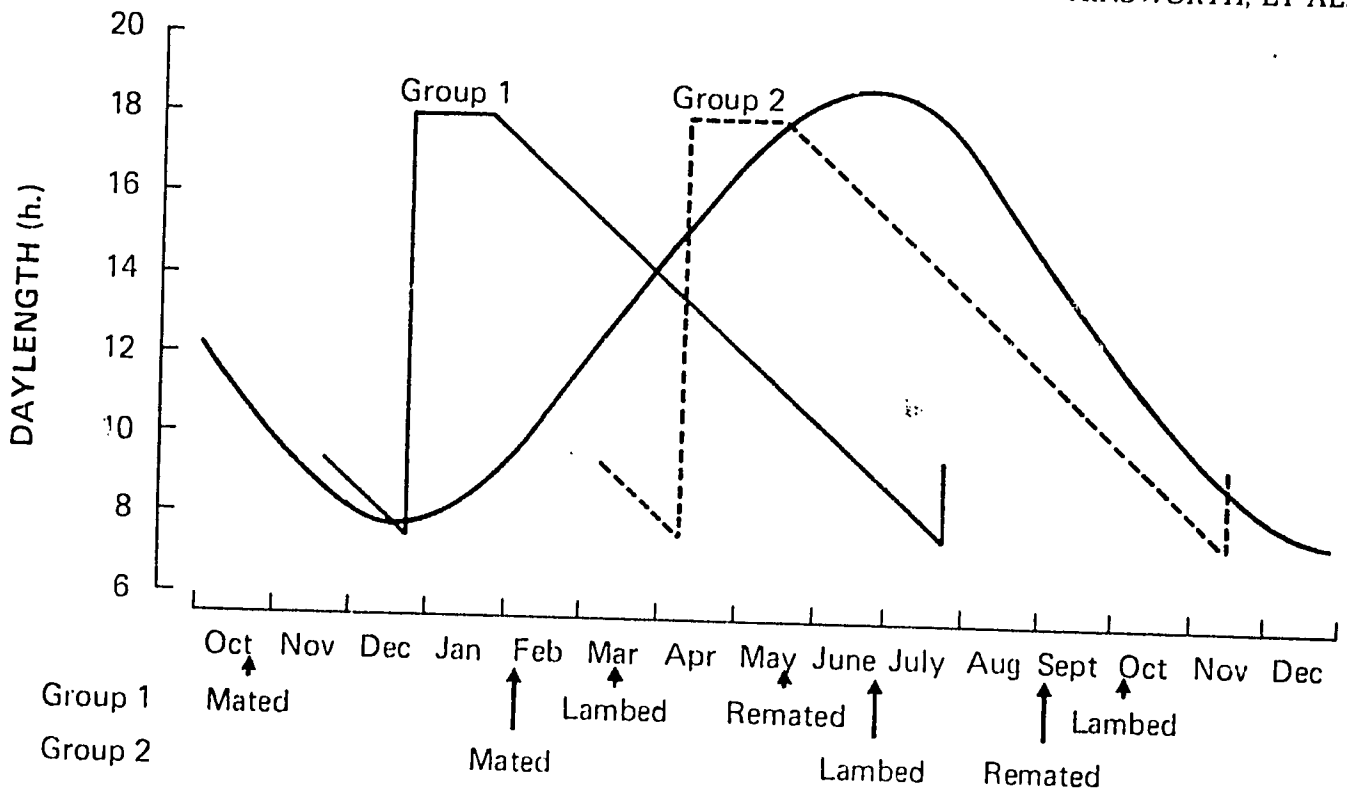

Figure 1. Artificial daylength patterns in relation to the natural daylength pattern used for each group of ewes in the total confinement system established at the Rowett Research Institute, Aberdeen, Scotland (from Robinson *et al.*, 1975).

the various disciplines have been integrated into the program is illustrated in Fig. 2.

A. **General breeding design.** Two synthetic female strains combining the highly prolific Finnish Landrace breed with other breeds in Canada are being developed for crossing to produce a prolific hybrid ewe. A synthetic sire strain composed mainly of Suffolk and Ile de France genes with minor contributions from seven other breeds is being developed for crossing on the crossbred ewe to produce fast growing, heavily muscled market lambs. Unselected strains of Suffolk and Finnish Landrace sheep are being maintained as genetic controls and a repeat mating scheme is being incorporated into the program.

The principal criterion for selection within the female strains is reproductive performance with lesser emphasis on lean meat yield and growth rate. Selection in the male strain is for growth rate and lean meat yield. It is expected that all three strains will adapt to total confinement, controlled reproduction under artificial light regimes and response to hormone treatment.

B. **Nutrition.** Lambs are removed from their mothers within 8–32 hr of birth, after being allowed sufficient time to obtain the necessary colostrum. They are then transferred to a lamb-rearing barn where they are fed milk replacer dispensed by pipeline. Because of the high cost of milk replacer, considerable emphasis has been placed on reducing the weaning age and developing more economical formulations. Currently lambs are weaned routinely at 21 days of age. Also, work conducted at ARI has indicated that lambs fed milk replacer containing 24% fat perform just as well as those fed milk replacer containing 30% fat (unpublished observations). A formulation containing the lower fat level now is standard.

Breeding ewes are fed almost exclusively an economical roughage diet, and growing lambs are fed a combination of roughage and concentrates. Considerable effort now is being directed at optimizing both of these diets for the intensively managed sheep.

C. **Control of the breeding cycle.** 1. **General procedures.** In March, 1974, the sheep population was divided into two equal groups: A & B. Group A was bred in May, 1974, and Group B in September, 1974. Subsequently, each group has been bred at 8-month intervals. The flock size is being increased up to the projected number of 1 600 breeding ewes through assignment of ewe lambs. Ewe lambs born under the Group A regime are assigned to Group B for breeding at 7 months of age and vice versa, on the basis of selection at the end of a 70-day test program.

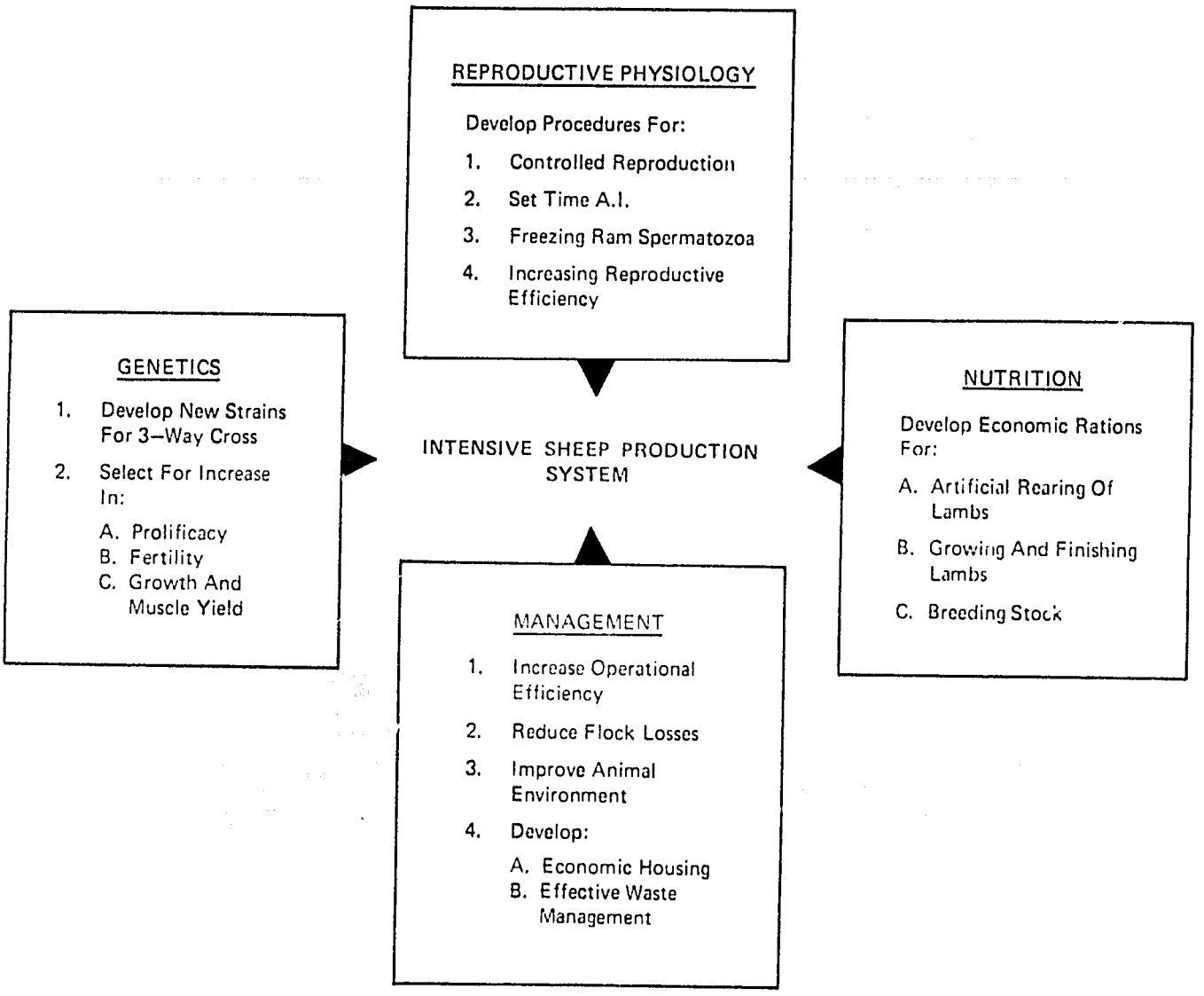

Figure 2. Integration of scientific, engineering and management inputs into the total confinement sheep production research program at the ARI, Ottawa, Canada.

Initially, Group A was placed under a light regime of 10 hr light, 14 hr dark, beginning March 11, 1974. From May 1, 1974, the light regime has alternated between 10 hr light, 14 hr dark and 18 hr light, 6 hr dark at four-month intervals. Group B was placed under the same light:dark ratio except that the regime was four months out of phase with that of Group A. Using these light regimes, the system is operated under a high light:dark ratio during the breeding period and early gestation and a low light:dark ratio during late gestation and the postpartum interval. It has been demonstrated that abrupt decreases in daylength can induce estrous activity in ewes (Ducker *et al.*, 1970; Ducker and Bowman, 1972; Rougeot, 1973). The objective of this regime is to induce estrous cyclicity in the ewes prior to synchronization of estrus so that such ewes will continue to cycle, thereby increasing the chance of the animals' being bred.

Adult ewes are synchronized, using sponge pessaries impregnated with either 30 or 40 mg FGA. The sponges are inserted for 12 days and 500 IU PMSG injected intramuscularly at the time of sponge removal. Subsequently, some ewes did not receive PMSG so that an assessment could be made of the effect of PMSG on fertility and prolificacy. Ewe lambs are treated with 40 mg FGA sponges for 14 days and 500 IU PMSG injected at sponge removal.

All ewes are bred following synchronization of estrus either by natural mating or artificial insemination ((AI). Rams assigned for natural mating are introduced to groups of 12 ewes during the 24 hr

TABLE 3. Overall lambing rates and litter size of ewes bred by natural mating after synchronization of the estrous cycle with FGA impregnated intravaginal sponges + PMSG at 8 month intervals under standardized total confinement conditions (see text)

Breeding Date	Group Bred	No. Ewes Bred	Ewes Lambing (%) 1st Service	1st & 2nd Service	No. Lambs Born	Litter Size
Sept., 1974	B	410	36.3	54.4	379	1.7
Jan., 1975	A	303	44.6	71.3	354	1.6
May, 1975[a]	B	520	12.7	49.2	387	1.5
Sept., 1975	A	252	40.1	67.1	327	1.9

[a]In May, 1975, all ewes were bred by AI at the synchronized estrus followed by natural mating at the subsequent estrus.

following sponge removal and remain with the ewes for a period of 21 days. Ewes to be bred by AI are inseminated with fresh extended semen or frozen/thawed semen either once or twice between 54 and 60 hr after sponge removal. Currently, the collection and preparation of semen and the number of spermatozoa inseminated is similar to that described by Colas *et al.* (1968) and Colas (1975a,b). Each ram provides sufficient semen to inseminate a group of 12 ewes. Rams are introduced into their respective groups at 5 or 12 days after AI and remain with the ewes for 9–16 days.

2. **Results to date.** A summary of the overall lambing and litter size, composite strain differences in litter size and effect of PMSG on litter size of ewes bred under the standardized total confinement conditions over successive breeding cycles is shown in Tables 3–5. From these data it can be concluded that incorporation of the Finnish Landrace genes into strains 2 and 3 and treatment of ewes with PMSG at the time of sponge removal is increasing litter size. Also, the overall lambing rate of the two synthetic dam strains (strains 2 and 3) is higher than that of the sire strain (strain 1).

Although these data are encouraging, it should be borne in mind that assignment of the ewes and rams for breeding is controlled by the genetic requirements. Of the animals assigned to a particular breeding, approximately 25% are ewe lambs of 7 months of age and 25% are ram lambs of the same age that have not previously been exposed to estrous ewes. It has been established that the lambing rate

TABLE 4. Composite strain differences in litter size of ewes bred by natural mating after synchronization of the estrous cycle with FGA impregnated intravaginal sponges + PMSG over three breeding cycles (Sept 1974, Jan 1975, Sept 1975) under standardized total confinement conditions (see text)

Strain[a]	No. Ewes Bred	Ewes Lambing (%)[b]	No. Lambs Born	Litter Size
1	218	55.0	166	1.4
2	277	59.9	293	1.8
3	360	74.2	497	1.9
4	74	37.8	45	1.6
5	36	75.0	59	2.2

[a]The breed composition of the synthetic strains (1–3) has been described by Gowe *et al.*, 1974. Strain 4 is purebred Suffolk and strain 5 is purebred Finnish Landrace.

[b]Overall percentage of ewes lambing after exposure to rams for two estrous cycles.

TABLE 5. Effect of PMSG treatment on litter size of ewes bred by natural mating after synchronization of the estrous cycle with FGA impregnated intravaginal sponges under standardized total confinement conditions (see text)

Breeding Date	Group Bred	No. Ewes Bred	PMSG Treatment	Ewes Lambing to 1st Service (%)	No. Lambs Born	Litter Size
May, 1974	A	205	500 IU	26.3	122	2.26
Sept., 1974	B	193	0	36.8	110	1.55
		216	500 IU	36.1	164	2.10
Jan., 1975	A	150	0	46.0	106	1.54
		153	500 IU	43.1	135	2.05
Sept., 1975	A	130	0	37.7	105	2.14
		122	500 IU	42.6	110	2.12

TABLE 6. Comparison of conception and lambing rates of ewes bred by set-time AI using fresh or frozen-thawed spermatozoa after synchronization of the estrous cycle with FGA impregnated intravaginal sponges + PMSG

Breeding Date	Time of Insemination After Sponge Removal (hr)	No. Spermatozoa Inseminated ($\times 10^6$)	Fresh Spermatozoa Conception[a] (%)	Fresh Spermatozoa Lambing (%)	Frozen Spermatozoa Conception (%)	Frozen Spermatozoa Lambing (%)
Sept., 1975	54 and 60	360	76 (59)[b]	75	53 (66)	41
Jan., 1976	54 and 59	450	60 (116)	51	27 (118)	23
May, 1976	56 and 60	450	82 (105)	—	35 (51)	—

[a]The number ewes pregnant was diagnosed by measurement of plasma progesterone levels in blood samples taken at 18 days after insemination, as described by Robertson and Sarda (1971).
[b]Number ewes inseminated.

of ewe lambs and of groups bred by ram lambs is 30–50% lower than that of mature ewes or of groups bred by mature rams, which lowers the overall lambing rate by 10–15%.

Beginning with the September, 1975, breeding, considerable effort has been made to improve the AI results by training the rams, using only high quality semen, comparing the use of fresh versus frozen/thawed spermatozoa and defining more clearly the limits to be observed in the timing of AI and number of insemination doses. These data are summarized in Tables 6 and 7. The fertility data obtained after breeding sheep by set-time AI using fresh spermatozoa compared favorably with the results of Gordon (1975b, 1976) and Colas (1975b). However, when using frozen/thawed semen, the conception and lambing rates were variable and were due, in part, to the differences in freezability of the semen obtained from the preassigned rams. More work is required to elucidate the variables which need to be controlled to obtain the most favorable conditions for good fertility.

TABLE 7. Comparison of single versus double insemination using fresh diluted spermatozoa on the conception rate of ewes bred by set-time AI after synchronization of the estrous cycle with FGA impregnated intravaginal sponges + PMSG

Breeding Date	No. Inseminations[a]	Time of Insemination After Sponge Removal (hr)	No. Ewes Inseminated	Conception[b] (%)
Jan., 1976	1	54	50	64
	2	54 and 59	67	57
May, 1976	1	56	52	83
	2	56 and 60	53	81

[a]All ewes inseminated with 450 × 10^6 fresh spermatozoa in 0.5 ml diluted semen at the times stated.
[b]See legend to Table 6.

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105.
Grazing Systems for Hill Lands

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The hill lands referred to in this paper are the 83.8 million hectares of Appalachia in 19 states from Maine to Alabama in the eastern United States. The topography ranges from steep Appalachian Mountain slopes to gently sloping foothills. Elevations range from 91 to 2 042 m. Annual rainfall ranges from 64 to 152 cm, and the growing season averages 250 days in the southern part of the region and 140 days in the northern part.

Soils are dominantly acid and were formed under a hardwood forest in the mixed mesophytic, oak-chestnut, hemlock-white pine-northern hardwood, and oak-pine forest regions.

Present land use in ha is: pasture, 8 903 400; cropland, 11 736 300; woodland, 53 825 100; and other land, 9 308 100. Four kinds of pastures and the extent of each in the region are:

	Hectares
Native[1]	5 210 451
Tame (improved)[2]	1 403 833
Woodland pastured[3]	5 024 959
Cropland used for pasture[4]	3 007 569
Total	14 646 813

More than one-third of the land grazed in this region is native pasture. Little bluestem (*Andropogon scoparius*) is the principal species on native pastureland that was used as cropland many years ago. Indiangrass (*Sorgastrum nutans*) is found in pure stands on lands that have never been plowed. Mountain oatgrass (*Danthonia compressa*) is the principal species on the grassy balds. These balds are found at the higher elevations, usually above 1 158 m, and produce abundant summer grazing. The introduced naturalized pastures consist of introduced plants such as orchardgrass (*Dactylis glomerata*), meadow fescue (*Festuca elatior*), and timothy (*Phleum pratense*) that have evolved over a period of time into a species or ecotype that can tolerate the low pH and fertility as the native species do. The so-called bluegrass pastures contain a mixture of species, including Kentucky bluegrass (*Poa pratensis*) and orchardgrass. Fertility, grazing management, pH, and other factors may determine which will be dominant. Other warm-season species such as low paspalums (*Paspalum* spp.) and panicums (*Panicum* spp.) may be prevalent during the growing season.

Improved pastures may be orchardgrass, Kentucky 31 fescue (*Festuca arundinacea*), timothy, reed canarygrass (*Phlaris arundinacea*), and redtop (*Agrostis alba*) in the northern part of the region.

More than 10 million animal units graze these hill land pastures. About 60% are beef cattle. Major production problems are overgrazing, brush management, steep topography, shortage of labor, and poorly drained soils.

More than one kind of pasture is generally found on a farm. Some may have as many as four. Helping farmers put these different kinds of pasture together in a planned grazing system designed to meet their objectives and fit the farm—its soils, plants, and livestock enterprise—has been very successful and appreciated. Soil Conservation Service personnel have assisted many farmers in developing grazing systems for their farms. The Extension Service has actively promoted winter grazing in their education program.

Until recent years, most Virginia cattle grazed during the growing season and were fed during the remaining three to five months of the year. Winter grazing was a missing link in farmers' grazing systems. Now many cattlemen use Kentucky 31 fescue for winter grazing and have reduced the cost of keeping a beef cow $40 to $50 per year. Winter hay requirements have been reduced from 80 to 15 or 20 bales per cow. Labor cost has been reduced 75 to 80%. Machinery and other operating costs also have been reduced. Grazing cattle have fewer health problems than those concentrated for winter feeding. Examples of grazing systems commonly used on Virginia hill lands are shown in Table 1.

Advantages of these grazing systems are optimum animal production at low cost; conservation of soil, water, and plant resources; and healthier, more productive plants that are less affected by drought than those that are overgrazed. The farmer also is able to take advantage of special features which make certain grasses more valuable, such as using fescue for winter grazing. Good grazing systems also add stability to the livestock industry which depends on grass as the primary resource base.

[1]Includes native grass, introduced-naturalized, and some of the bluegrass pastures.

[2]Permanent tame pasture, perennial plants.

[3]Woodland grazed intermittently or regularly.

[4]Pasture in a cropping system.

TABLE 1. Planned grazing systems used in Virginia

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ky 31 Fescue	x	x	x		hay		x	*			x	x
Bluegrass-Clover				x	x	x		x**	x	x		
Ky 31 Fescue	x	x	x			x		*				x
Bluegrass-Clover				x	x			**		x	x	
Orchardgrass-Clover					hay			**	x			
Little Bluestem							x	x				
Orchardgrass-Clover				x	x			x**	x			
Bluegrass-Clover						x	x	**		x	x	

*Apply lime, phosphate and potash according to soil test plus 36–41 kilograms of nitrogen annually.
**Apply lime, phosphate and potash according to soil test.
x = Graze.

In order for a grazing system to function smoothly, the growth and physiological requirements of the plants must be met. Overgrazing has been common on hill lands for many years. It lowers production and weakens and may actually kill the plants. Fencing may be needed to separate pastures with different grasses and prevent overgrazing.

One of the first steps in planning a grazing system is to achieve a balance between grazing animals and the grass produced. To do so, farmers may need to sell cows. Most farmers with a grazing system use a medium level of management and achieve proper use by stocking at the rate of slightly over one ha of established grass per animal unit yearlong.

Proper grazing use helps maintain enough leaf surface on the grass plant for maximum photosynthesis and consequent high production. Rotation grazing also is built into these systems. This allows replenishment of root reserves, seed production, accumulation of growth for hay or future grazing, and harvesting at the optimum time.

Management requirements for different plants in the system vary because of plant type, growth habit, season of growth, and other reasons. Meeting these growth and physiological requirements, especially proper grazing use, is essential for optimum production and conservation of the resource base.

Planned grazing systems are becoming more popular with farmers in Appalachia because of their many advantages. At least 15% of Virginia's cattlemen have them or are in the process of establishing them. More are being planned.

DISCUSSION

F. P. Horn (Oklahoma, USA). There have been suggestions that the cattle we produce now off pasture are not in as good a condition as they were several years ago, and that this has been attributed to an increased use of nitrogen fertilizer. Do you feel there is a relationship?

Trew. I would agree that individual animal performance on many farms has declined in recent years. However, I would attribute this rather to a lesser use of fertilizer or pasture with the increased cost of nitrogen. This has been aggravated by drought conditions in the Piedmont area of Virginia.

K. F. O'Connor (New Zealand). Could you give us some idea of the grazing duration per grazing time that you are recommending in your management systems—for example, on your Kentucky bluegrass—white clover pastures in summer and tall fescue pastures in winter? I am concerned about the amount of unconsumed dead matter that I see on the pastures from your slides.

Trew. It takes about 0.5 ha of Kentucky 31 fescue to carry a cow through the winter, and this provides 120 grazing days. Grazing duration on other species will depend on acreage available and management.

O'Connor. Are you using a rotational grazing system or period set stocking?

Trew. We encourage farmers to use the grass as a guide to management. On Kentucky bluegrass, for example, livestock are moved to another pasture when the herbage is grazed down to about 5 cm.

106.
Utilization of Pennsylvania Hill Land Pastures for Beef Production

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Pennsylvania has approximately 700 000 ha of pastureland that is too hilly, rough, rocky, shallow, or brushy to be used for cultivation. Soils on these sites vary from well-drained to droughty to those with poor internal drainage. Soil pH varies from 4.5 to 5.5. Generally, they are low in phosphorus (P) and their potassium (K) level is variable depending upon the parent material from which they were formed. Soils derived from the shales generally have adequate levels of K while those of limestone and sandstone origin are low in K.

Experiments within the state have demonstrated that by the application of moderate levels of soil amendments and the seeding of adapted forage species, sufficient forage can be produced to grow out calves for subsequent fattening or to support cow and calf operations (Sullivan *et al.*, 1959, 1969; Washko and Phillips, 1966; Washko and Wilson, 1974). These experiments were conducted on soils which varied in depth from a few cm with rock outcrops to those several m deep. Annual precipitation ranged from 900 to 1 000 mm with variable seasonal distribution.

Results from three large-scale experiments will be cited to indicate the beef production potential of such hill land pastures; (1) a grazing experiment with steers, (2) a crossbred dairy-beef cow and calf operation, and (3) a crossbred beef cattle cow and calf operation under different management levels. Two experiments were conducted at the Rockview Correctional Institution in central Pennsylvania (40°47′ N; and 77°51′ W), whereas the third was located in western Pennsylvania (40°15′ N; 79°39′ W).

Pastures in these experiments were reclaimed from abandoned cropland which had reverted to weeds, briars, brush, and poverty grass (*Danthonia spicata*) with limited amounts of Kentucky bluegrass (*Poa pratensis*) and Canada bluegrass (*Poa compressa*). Sites were characterized by moderately undulating to rolling relief transversed by slopes with grades up to 15%. In central Pennsylvania the soils were of three types: (1) fine, mixed mesic typic hapludalfs (Hagerstown series); (2) clayey, illitic, mesic typic hapludults (Hublersburg series); and (3) fine-loamy, mixed, mesic ultic hapludalfs (Morrison series). At the western location the soils were: (1) fine, mixed, mesic aquic hapludalfs (Guernsey series) and (2) fine-loamy, mixed, mesic ultic hapludalfs (Westmoreland series).

When brush was present it was cleared with a bulldozer. Old vegetation was destroyed by tillage with a disk plow and subsequent disking. Limestone and P and K were applied in accordance with soil test results. Forage grasses alone and in legume mixtures were band seeded on prepared seedbeds with spring oats as a companion crop on the steep slopes where soil erosion was a problem. Both grasses alone and legume-grass swards received maintenance applications of P and K each fall in accordance with soil tests. When soil tests indicated low magnesium (Mg) levels, dolomitic limestone was used not only to apply the Mg but also to correct soil acidity. Since nitrogen (N) levels utilized on the grasses alone and the forage species in the three experiments differed these will be discussed under the specific experiments.

Pastures were laid out and fenced for rotational grazing. Five pastures were assigned to each group of cattle. An animal unit in the central Pennsylvania experiments was considered the equivalent of an animal weighing 454 kg liveweight. Animals were stocked at rates which varied from one animal unit for 0.4 ha to 2.0 ha. Cattle were turned on pasture the first week of May when the forage reached a height of 12 to 25 cm and remained on pasture until all edible forage was consumed, between October 15 and November 15, depending upon growing conditions of the season. The exception was at the western experiment, where the cattle remained on pasture the year around. Surplus pasturage was ensiled in trench silos or was removed as hay and baled in large round rolled bales or in compressed stacks for feeding during droughty periods if needed, or in winter. At the western Pennsylvania site the cattle fed on the large round bales during the months pastures were unproductive or dormant.

Pastures were clipped periodically during the grazing season to control weeds and remove unpalatable growth as well as to encourage regrowth of the species. Dung islands were spread by means of chain harrow each autumn after termination of the growing season except at the western Pennsylvania experiment. Cattle on all experiments had

access to calcium (Ca)-P trace mineral mixtures and salt.

ROCKVIEW STEER GRAZING EXPERIMENT

This area consisted of 74 ha divided into 22 pastures, ranging in size from 2.8 to 4.9 ha, and followed natural contours and boundaries. The forage species and cultivars seeded at this site were: common, S-37 and Pennlate orchardgrass (*Dactylis glomerata*), Lincoln smooth bromegrass (*Bromus inermis*), common reed canarygrass (*Phalaris arundinacea*), and common Kentucky bluegrass seeded in pure stands. Legumes seeded with each of the already listed grasses were Buffalo and DuPuits alfalfas (*Medicago sativa*), Empire and Viking birdsfoot trefoils (*Lotus corniculatus*), and ladino clover (*Trifolium repens*). The grasses in pure stand were fertilized with 180 kg of urea nitrogen/ha in four split applications of 45 kg/ha each and these were applied prior to the first grazing and following each grazing except the last for the season. Four rotational grazings were made on each pasture per season.

Beef production per ha was compared using yearling Hereford steers grazing N-fertilized grass swards alone and legume-grass swards with and without grain supplementation on pastures during the 1957–61 period. Grain supplementation consisted of 2.3 kg of ground grain (85% maize and 15% oats) and 0.45 kg of 36% protein concentrate per head daily. Steers were implanted with 24 mg of diethylstilbestrol in the ear.

Results are presented in Table 1. Beef production for the grazing season of 176 to 209 days averaged from 342 to 408 kg/ha. Cattle gains on N-fertilized grass swards and legume-grass mixtures, although slightly favoring the legume-grasses, were not different ($P > .05$).

Feeding of concentrates on pasture increased beef yield by 60 kg/ha on the N-fertilized and 41 kg/ha on the legume-grass mixtures. Beef production on N-fertilized grass and legume-grass mixtures with grain feeding was similar. However, grain feeding on both sward types increased beef production per ha grazed ($P < .05$). It would have required from .04 to .05 ha of maize (*Zea mays*) and from .02 to .03 ha of oats (*Avena sativa*) per steer to furnish the concentrates fed over the 176- to 209-day grazing period based on yield levels of 7 846 kg/ha for maize and 2 511 kg/ha for the oats.

Cattle were slaughtered and graded at the end of each grazing season. Dressing percentages and conformation scores were not materially influenced by sward types. Grain feeding on both sward types increased dressing percentage and conformation scores slightly. Differences in dressing percentages and conformation scores due to grain feeding were obtained only with the legume-grass mixtures.

The vulnerability of hill pastures to droughts is illustrated by this Rockview steer grazing experiment. In 1962, central Pennsylvania experienced a severe drought. Instead of the average 900 to 1 000 mm of rainfall normally expected, only 755 mm of rainfall fell. The four summer months of May, June, July, and August received only 233 mm of precipitation instead of the normal 610 mm. This 61.8% precipitation deficit resulted in a drastic reduction of pasturage for beef production. Beef production per ha on pasturage alone on integrated swards of legume-grasses and N-fertilized grass averaged only 240/kg/ha for 1962 compared with an average of 355 kg/ha for the 1957–61 years, or a reduction of 115 kg/ha associated with the drought (Washko and Phillips, 1966).

ROCKVIEW CROSSBRED DAIRY-BEEF COW AND CALF EXPERIMENT

Prior to assignment to the experiment the 126 ha of land were utilized as follows: 55 ha were in permanent pasture, 61 were strip cropped in a maize-oats-wheat-hay rotation, and 10 were in hay.

TABLE 1. Beef production on renovated hill land pastures at Rockview, 1957–61

	Liveweight Steer Gains on Pastures Under Different Feeding Systems (kg/ha)				
Years	N-fertilized Grass	Legume-Grass Mixtures	N-fertilized Grass With Concentrates	Legume-Grass Mixtures With Concentrates	Grazing Days Furnished per Season per ha
1957	341	403	413	403	376
1958	336	301	368	383	353
1959	358	373	388	460	462
1960	366	395	445	427	516
1961	311	361	395	366	489
Average	342	367	403	408	439

L.S.D. at .05 level = 37 kg.

This area was divided into 23 pasture paddocks which ranged from 2.4 to 10.5 ha depending upon terrain and natural boundaries. The permanent pastureland was retained in pasture but was divided into five paddocks.

Forage species in these five permanent pasture paddocks were estimated to be 80% Kentucky bluegrass, 10% orchardgrass, 5% white clover (*Trifolium repens*), and 5% quackgrass (*Agropyron repens*). Vegetation on the hayland consisted of 80% orchardgrass and 20% timothy (*Phleum pratense*). The last crop in the strip-cropped area was wheat (*Triticum vulgare*) overseeded with orchardgrass alone or with birdsfoot trefoil, smooth bromegrass, or reed canarygrass. The forage cultivars seeded were common orchardgrass, Pennmead orchardgrass, Saratoga smooth bromegrass, common reed canarygrass, and Viking birdsfoot trefoil.

Four to five pasture paddocks were assigned to each of five Holstein-Angus F_1 crossbred cattle groups ranging from 38 to 50 head and their calves at a stocking rate of 0.57 ha per cow and calf until July 1 and 0.63 ha for the remaining grazing season. Pasture swards of each forage species were allotted for grazing by each cattle group, in so far as possible. In addition to the fall maintenance applications of P and K, two 50 kg annual nitrogen/ha applications were made, the first in early spring, the second in early July on all paddocks in grasses alone and on legume-grass swards when the legume stand dropped below 30%.

The 190 to 210 crossbred cows carried on this experiment were bred artificially to Polled Hereford, Charolais, Limousin, and Simmental bulls over a 45-day period, then exposed to natural service for an additional 25 days. During wintering, hay and silage, supplemented with pea and corn canning-waste silage, were fed in required amounts but without supplemental concentrates. The calves received creep feed at eight months of age and were weaned at nine to ten months.

Some idea of the productivity of the forage species under grazing on the soils and climatic conditions of central Pennsylvania can be obtained from Table 2. Kentucky bluegrass yielded less pasturage than the tall-growing grasses such as orchardgrass, smooth bromegrass, or reed canarygrass. This is because Kentucky bluegrass goes into summer dormancy when soil temperatures rise above 27 C (Brown, 1939). Kentucky bluegrass also furnished the lowest number of grazing days per ha per season, 72 less than the N-fertilized orchardgrass and 88 less than the birdsfoot trefoil in any mixtures with orchard, smooth brome, and reed canary grasses.

The value of hill pastures for a cow-calf herd is illustrated in Table 3 by one of the crossbred Holstein-Angus cattle groups at Rockview. Animals in the group averaged 38 cows and 39 calves on five pastures totaling 24 ha. Calves gained an average of 217 kg/ha and the cows 67 kg/ha over the three-year (1970–72) grazing seasons. In addition, one cow per season was culled and replaced by a first calf heifer whose weight averaged 82 kg less per season than the animal she replaced. Hence, another 3.4 kg/ha of liveweight should be credited to the pasture system.

Not all the weight gained by the calves can be attributed directly to the forage since part of the weight gain is obtained from the milk provided by the cow. Thus, in a cow-calf operation the growth and the gain in weight of the calves and the weight differences in cow replacements on pasture represent the beef produced per ha.

CROSSBRED BEEF COW AND CALF EXPERIMENT UNDER DIFFERENT MANAGEMENT LEVELS

This experiment is located at the western Pennsylvania Forage-Beef Farm approximately 30 km from Pittsburgh and is being conducted currently (Planning and Supervision Committee, 1976). The land area is divided into three production units. Unit A consists of 69 ha of pasture and hayland and

TABLE 2. Productivity of several pasture species under grazing by crossbred Holstein-Angus cows and calves on hill pastures at Rockview, 1970–72

	Dry Matter (MT/ha)				Grazing Days/ha/A.U.[b]			
Pasture Species	1970	1971	1972	Avg.	1970	1971	1972	Avg.
Kentucky bluegrass	8.94	5.16	5.38	6.50	277	264	301	281
Orchardgrass	9.04	6.82	5.92	7.26	356	398	304	353
Birdsfoot trefoil-grass[a]	8.68	6.17	6.26	7.04	393	427	287	369
L.S.D., .05 level	.34	.39	.26	.32				

[a]Orchard, smooth brome, or reed canary.
[b]Animal unit (A.U.) equivalent of 454 kg liveweight.

TABLE 3. Beef production on hill land pastures with cross-bred Holstein-Angus cow and calf herd, Rockview, 1970–72

Year	Animal Numbers Cows	Calves	Hectares Grazed	Animal Gains on Pastures* (kg/ha) Cows	Calves
1970	41	43	24	94	239
1971	38	39	24	85	211
1972	36	35	24	23	201
Average	38	39	24	67	217

*3.4 kg/ha should be credited to pastures on cow replacements due to weight differences of replacement.

is stocked at one cow and calf per 0.8 ha. Lime and fertilizer are applied according to soil test recommendations on this unit. Pastures are clipped as often as needed. Unit B has 28 ha of pasture and hayland. Stocking rate is one cow and calf per 1.2 ha. Lime is applied when soil pH drops below 6.0 and fertilizer is applied at only one-half the recommended rate based on soil test. Pastures are clipped only once. Unit C is composed of 25 ha of pasture and hayland and is stocked at the rate of one cow and calf per 2.0 ha. Soil pH in its pastures ranges from 5.4 to 6.0. No lime or fertilizer is used on this unit except for minimum amounts for establishment of hay stands. Clipping of pastures is not practiced.

There are several permanent pastures among the three units. Kentucky bluegrass is the dominant forage species on these pastures with variable amounts of redtop (*Agrostis alba*), white clover, and quackgrass present. A majority of the pastures consist largely of orchardgrass and quackgrass with small amounts of white clover. Hayfields consist of orchardgrass, timothy, quackgrass, and less than 25% alfalfa in old stands on units A and B. The hayfield on Unit C was seeded to a mixture of red clover (*Trifolium pratense*) and timothy.

Two pastures in Unit A and one in Unit B were seeded to tall fescue (*Festuca arundinacea*) and ladino clover for winter grazing. Legumes, particularly birdsfoot trefoil, are being introduced into the pastures via the sod-seeding technique. N has been applied in two increments of 56 kg/ha each on Unit A and one increment of 56 kg/ha on Unit B pastures. Surplus pasturage and hay are baled in large round bales for winter feeding.

All cows remain on pastures and on hay aftermath the year around without overhead shelter. Cows are wintered on standing hay aftermath and large round bales which remain in place as baled until consumed. A 56-day calving season starts during March 12 to 15, annually. A crossbreeding program is followed for each unit with bulls exchanged among units in successive years.

Because not all pastures and hayfields were utilized fully and reseeding of several of the pastures and hayfields was necessary, beef production per ha as indicated by calf weight would not be meaningful for the first two years, 1974–75, of the experiment. A better indication of the productivity of the pastures and hayfields was their carrying capacity as utilized (Table 4).

TABLE 4. Carrying capacity of hill land pastures under different levels of management of crossbred cow and calves, 1974–75

Management Level	Carrying Capacity—Cow* Days/ha Grazing Only	Winter Graze and Hay Feeding
Unit A-high	502	526
Unit B-medium	413	549
Unit C-low	215	284

*Any animal one year old or older.

As would be expected, pastures on Unit A with the highest fertility and more intensive management provided 502 cow days of grazing and Unit C with the lowest fertility and least intensive management furnished only 215 cow days of grazing per ha. Unit B, the medium fertility and management unit, was intermediate in carrying capacity, furnishing 413 cow days of grazing/ha.

Under the winter grazing large round bale system, the high fertility and intensive management Unit A and the medium fertility and intensive management Unit B each furnished over 500 cow days/ha of grazing and feed. The low level of fertility and management system provided only 284 days of grazing and feed.

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DISCUSSION

Unidentified. Did your experimental work show that you could maintain the soil pH above 6.0, put on four applications of 56 kg N/ha, and make any money?

Washko. Since this work was conducted at the State Penitentiary, it isn't possible to make estimates of labor costs. The amount of labor involved was certainly higher than we would encourage under commercial farm conditions.

J. E. Winch (Guelph, Canada). You mentioned that you maintained your trefoil systems for 8–9 years. In that period, did you allow it to reseed?

Washko. Yes. Early in springtime when we first started the system we grazed the N-fertilized grasses first and let the legumes get further along. Often the birdsfoot trefoil would have reseeded by the time we used it.

Winch. Do you think that's necessary under Pennsylvania conditions?

Washko. The longest stand that I was able to keep from one seeding was seven years; the first birdsfoot trefoil stand there was introduced in 1940 and lasted 33 years, but probably did not contain the original plants. I think you should allow periodic reseeding because you can get winter killing or disease build-up. This is why we are particularly interested in Dawn birdsfoot trefoil, from Missouri, because we do get years when Rhizoctonia knocks out our trefoil stands. Persistence is generally better in northern than in southern Pennsylvania.

Unidentified. Reed canarygrass interests me as a possibility for early grazing. I noticed that you used it in mixtures with trefoil. Was this the Empire variety?

Washko. We used Viking trefoil with reed canarygrass and Empire trefoil with Kentucky bluegrass.

Unidentified. I was surprised to see that you didn't graze the reed canarygrass-trefoil combination until the third week of May. Why didn't you start earlier?

Washko. Birdsfoot trefoil is slower getting started, as you know, and we wanted to give it a chance to develop. So we grazed the N-fertilized grass first.

Unidentified. Our experience is that you should graze such a combination early to take the grass out and maintain the legume component.

107.
Sheep and Cattle Pastoral Grazing Systems on New Zealand Hill Country

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The stimulus for development and management of hill country grasslands in New Zealand over the past 20 years has been largely initiated by the basic classical research carried out at the Hill Country Research Station at Te Awa (Suckling, 1956, 1975), though its application is complicated by the wide diversity of hill country throughout New Zealand.

The two main islands extend from 34° to 47° S and from 166° to 179° E. They are both very hilly and mountainous, more than 75% being over 200 m, and 223 named peaks are over 2 300 m. There is a wide variation in local climates, mean annual rainfall varying from 350 mm to over 3 000 mm in different farming districts and mean temperatures vary tremendously from the far north to the far south, affecting the general growth pattern of pastures throughout; e.g., mean annual air temperatures (*N.Z. Official Year Book*, 1975) in the far north (Kaitaia) 15.3 C, maximum 28 C, minimum 2 C and in the far south (Invercargill) 9.5 C, maximum 28 C, minimum −5 C.

Of the total area of 26.9 million ha only 14.2 million ha is productive, including 8.5 million ha in improved pasture and hill country pasture and 5 million ha in tussock grasslands, much of which is unimproved. Topographically, about 50% of the total land mass is classed as steep and mountainous, 30% moderately hilly and 20% rolling and flat. There is a further distinction between the "hill country" and the "high country" in the South Island and the "hard hill country" in the North Island, these latter two being mainly above 600 m and in the central mountainous chain.

Because of these wide differences in topography and climate, the hill country grazing management systems of sheep and beef cattle vary from district

to district and have to be adjusted and adapted to fit local problems. There is, therefore, no system common to all parts of the country, but there are common basic principles involved and these are largely associated with my own experiences.

In 1975–76 we had 55.3 million sheep and 6.5 million beef cattle in New Zealand of which a large proportion are run on the hill country. The overall increase in these livestock since 1963–64 is 10% and 81%, respectively (Taylor, 1976).

A major contributing factor to this national increase has been the development of hill country land, which has raised soil fertility and improved pasture production. This has been achieved, principally, by applying superphosphate fertilizer, introducing clovers and higher producing grasses, and by a number of supporting capital improvements such as fencing, water supply, access tracks, drainage, shelter, and the breeding of the extra livestock needed.

Within this context, farmer management of hill country pastures and livestock assisted by scientific expertise has taken on a new dimension to develop techniques which will help farmers maximize production efficiency at minimum cost and effort (labor). One of the most important of these has been to introduce better systems of grazing management (either new systems or by adapting systems originally developed for the more intensive flat and easy land to meet the new situation in the hill country).

GRAZING SYSTEMS

First and foremost, we regard pasture as a permanent crop, to be utilized in situ throughout the year; second, most farmers with developed hill country find that they can rely on grass entirely, including the grass products of hay and silage, to feed their livestock. This is a situation which we term "all grass farming." Not all farmers can use this system for various reasons, and in the colder zones and drought areas it is sometimes necessary to grow supplementary feed crops, mostly brassicas.

The three main periods throughout the year during which systems of grazing management are likely to vary are spring, summer-autumn, and winter. In the spring, grazing management will be predominantly set stocking; in the summer-autumn mainly rotational grazing; and in the winter rotational grazing, set stocking, and some other systems.

Rotational Grazing

There has been much research throughout the world on the underlying benefits of rotational grazing. Most of the research indicates that if pastures are grazed for a short period and spelled for a long period, extra feed can be grown and pasture composition improved. Depending on the stocking rate intensity, the main requisites for success are good drainage, intensive stockproof sub-division, good water supply and, most important of all, high fertility pastures, all of which are limiting on the hill country.

This is the only grazing system generally believed worth considering; in theory it has a great deal of support, but in practice it is not always desirable. Under certain conditions it can have major disadvantages, compared with alternative systems. Our hill country farms are quite large (average 250 ha to 2 000 ha) and pose many problems for an ideal system of rotational grazing. Sub-division is extensive but costly, steepness and contour add problems, as do water supply and wide variations in soil fertility, pasture species, weed problems, and the climatic difference between sunny and dark faces.

The ideal period for grazing each paddock or sub-area is about three days, rotating around about 20 paddocks, but the length of the cycle is variable, according to growing conditions. In winter and summer drought areas, the cycle varies from about 35 days in the north to 60 days in the south, but the number and variable size of the paddocks creates real problems, especially when several mobs are to be rotated on separate blocks. In such cases the period of grazing is often too long and the spelling too short. This can be partly overcome by using one mob of livestock and rotating around the whole farm (Smith *et al.*, 1976). During the season it is necessary to adjust the grazing cycle, shortening it in fast growing periods and lengthening it when growing conditions are poor.

Set Stocking

Efficient set stocking at full pasture control stocking rates is a very simple and cheap system of grassland management. It solves many of the practical and cost problems of rotational grazing and is widely used in hill country practice.

Critics of set stocking see it as a continuous grazing system with all the results of lax and selective grazing, low stocking rates, coarse herbage showing up in poor pasture species and low production. In my experience in the system I have called efficient set stocking this does not happen.

Efficient set stocking under our conditions can be flexible to give consideration to both pastures and livestock—e.g., (a) allows grazing periods when stock should not be disturbed; (b) the higher producing paddocks can be stocked at higher rates; and (c) livestock can be fed to equalize bodyweight.

Normally, no extra subdivisional fencing is required and each paddock can be stocked to its productive capacity. Controlled set stocked sheep and cattle are more settled, a distinct advantage at lambing and calving time and for the easy-care types of sheep now being bred in New Zealand i.e., sheep that require the minimum of shepherding.

Trial comparisons of rotational grazing vs. set stocking are well documented and in the majority of cases there is no difference except under conditions of high soil fertility and intensive development and management (McMeekan, 1960). Also (Suckling, 1956, 1975) found set stocking to be quite practical in his research trials on hill country management.

Seasonal Grazing Management

Spring. Rotational grazing is not favored in the spring from just before lambing and calving until weaning. This constant shifting of ewes and lambs, cows and calves in large mobs, tends to cause mis-mothering, poorer animal growth, pugging (pasture treading) and more labor pressure. Most farmers on the hills like to leave their sheep and cattle set stocked at this time. Full utilization is seldom difficult with adequate stocking rates. As the spring growth gains momentum it can be controlled by shutting off some paddocks for hay and/or silage and also by bringing in extra cattle.

Summer-Autumn. From lamb weaning onwards, rotational grazing in various forms is the most practical management aid for controlling summer surplus growth, seedhead development or reversion to lower producing pasture species and helping to maintain a leafy, palatable, and digestible sward. This latter is very difficult to achieve either by a set stocking system or by continuous grazing, especially on pastures with low-producing species, which tend to predominate on hill country.

Winter. Although we do experience periods of severe weather, we do not have to house our livestock in the winter, which is one advantage we have in keeping our cost of production down. Also, if we can rely entirely on grazing pasture plus hay or silage, which we call "all grass wintering," this helps to keep costs down.

Winter grazing management is much more critical, especially in the far south where the winter lasts about 100 days, compared with 60 days or less in the north. A slow rotational grazing system for sheep and cattle at this time is widely practiced. However, in wet and poorly drained areas, hoof tramping damage to pastures (Edmond, 1970) can be a severe problem with heavy stocking rates, because pastures and gateways often become a sea of slurried mud, causing stress and temporary starvation to stock. This can be partly overcome by speeding up the rotation or by set stocking.

Winter set stocking also is widely and successfully practiced by hill country farmers, quite often without any supplementary hay feeding, e.g., on oversown and top-dressed tussock hill country in South Otago in paddocks of approximately 30 ha, six ewes/ha plus 0.4 cows/ha are grazed throughout the winter, in many cases without supplementary hay. In the North Island many developed hill farms are carrying over 12.5 ewes/ha without hay feeding. Under this system, at adequate stocking rates, we find no evidence of selective grazing or overgrazing; finger and thumb grazing 2.5 cm in height is always available and the sheep maintain themselves in a very healthy and fit condition.

Block Grazing

Block grazing (Du Faur, 1972) is a system successfully used by dairy farmers and can be adapted by hill country farms that have some flat or easy sloping, well-drained, high fertility pasture that can be used for a special purpose, such as wintering young fattening cattle or young bulls. The block usually comprises six paddocks of about 2 ha, with trough water laid on. These are sub-divided again, each into four further grazing areas with electric fencing, making 24 grazing lots. The pasture is spelled in the autumn, in order to get a good length of pasture ahead. When grazing commences in early winter, the cattle are grazed on a one- to two-day per lot rotation throughout the winter, supplemented if necessary with hay. This system is labor intensive and requires good forward planning and extra fertilization including nitrogen.

On and Off Grazing

This is another successful grazing system, particularly for farms not advanced in development and fertility. It relies principally on "winter saved pasture": Closing off about one-third of the grazing area in the late autumn, another third in early winter and carrying all the livestock on the remaining third until past mid-winter; rotating around the area and giving a supplementary ration of hay and/or silage. In the latter period of winter, the stock are allowed a ration of the saved grass for about one hour per day and then put back on to the wintering area. Feed can be budgeted to last through the winter with excellent results in building up the soil fertility of the wintering area with heavy concentrations of dung and urine. As development increases with the raising of soil fertility and more productive pasture this system is usually superseded by rotational grazing or set stocking.

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108.
Comparison of Hay Package Types for Beef Cow Wintering Programs*

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Within the past five years, large hay packaging systems have become popular with U.S. beef cattle producers. Most of the experiences with outside-stored hay packages until recently have been with the small round bales, weighing approximately 23 kg. Early research with these small packages indicated moderate losses in forage quality and quantity, if restricted feeding practices were used (Bratzler, 1955; Wilson *et al.*, 1966). Lechtenberg *et al.* (1974) observed approximately 25% more forage loss if feeding gates were not used. Schrock *et al.* (1975) have summarized power and labor requirements of various hay harvesting systems. However, critical trials are lacking on the relative amounts of forage required and performance of beef cows wintered on large, outside-stored hay packages compared to conventional, barn-stored rectangular bales. The primary objectives of these trials were to determine the carrying capacity and performance of several different wintering systems, so that this information would be available as a producer considers changing from a conventional hay handling system to a large hay package, outside-stored system. Additional information was also obtained to compare harvested corn stalks with hay feeding systems, and on the effects of chemical treatment of hay packages.

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MATERIALS AND METHODS

Trial I

Four different hay harvesting systems were compared; conventional rectangular bales, large round non-string tied bales, large round string-tied bales, and one-ton hay stacks. Machines for the four methods were obtained, respectively, from New Holland, Hawk-Bilt, John Deere, and Hesston companies. The hay fields from which the forage was taken in mid-June (orchardgrass, reed canarygrass, bromegrass with 50% or less of birdsfoot trefoil) varied in size from 2 to 7 ha. Within each hay field, alternate windrows were harvested by each of the four machines. The rectangular bales were barn-stored and the large bales and stacks were moved within two weeks after harvesting to a centralized outdoors storage area.

Two stacked corn stalk treatments were included. One stack treatment involved anhydrous ammonia applied during stacking and the other treatment had no chemical applied. A cold-flow ammonia application process was used to apply 8.2 kg of N/MT of forage dry matter (Horne, 1975).

Sixty April–May calving cows were randomly allotted to six lots with stratification on weight, age, estimated gestation stage, and initial condition (fatness) score. The 131-day trial was initiated in late December. A free-choice combination mineral-protein supplement (containing biuret, crude protein content, 101%) was available to all groups.

The large packages were fed individually in three-sided fence-line feeders, on an open, uncovered concrete floor. The cows were confined in open 30.5 × 38 m lots with a woodland wind break on the

southwest. All large hay packages were fed one-at-a-time, *ad libitum*, with the amount of refused forage accumulated, weighed, and sampled for moisture content after each third package was fed. The rectangular bales were fed *ad libitum* for the first and last 28-day periods, and on a limited basis from day 29 through 103 (*ad libitum* fed cows were gaining too much weight). Neither cornstalk group received supplemental feed until day 103 when an additional 2.3 kg of alfalfa hay was fed per head daily. Each fifth large hay package, within each type, was sampled with a forage sampler probe. Rectangular bales were sampled on each seventh day of feeding.

Trial II

The first cutting of an alfalfa crop was harvested as rectangular bales (New Holland), round bales (John Deere), and one-ton stacks (Hesston). The crop was cut at an early bloom stage, conditioned, and left in a swath. Moisture content was obtained each 0.5 hr until in the 35–40% range. An 80% propionic acid, 20% acetic acid mixture (Celanese Chemical Co.) was diluted with water in a 50:50 ratio and applied at the rate of 1% active chemical per ton of raked hay. The chemical was applied to the windrow during raking. The nontreated hay was field-cured and baled at 20% moisture. Equal quantities of the hay were baled through each packaging machine.

RESULTS AND DISCUSSION

Trial I

Rectangular bales averaged less ($P < .05$) for acid detergent fiber (ADF) than any other forage (Table 1). However, there were significant differences in ADF percentage among the three different types of outside-stored large hay packages. Crude protein of the four types of hay packages were not different, except in comparison of rectangular bales vs. non-tied round bales ($P > .05$). Available protein (calculated by substracting ADF-protein from crude protein) was higher ($P < .05$) for barn-stored rectangular bales than for any other types of forage. There was no significant difference in ADF-protein among the three types of outside-stored packages, although the non-tied round bales tended to have a higher percent of ADF-protein, which was reflected in the lower available protein content. One possible reason for increased ADF-protein in the outside-stored bales is the heating that results from moisture accumulating in the large hay package from rains or high ambient moisture (Nehrir, unpub.). Since crude protein of treated cornstalks was 1.1% greater than in untreated cornstalks, only 20.5% of the added nitrogen was retained. ADF-protein averaged 0.9 and 1.6% for cornstalks with and without anhydrous ammonia, respectively. Available protein content of ammonia-treated cornstalk stacks was only 0.4% greater than in non-treated cornstalk stacks.

TABLE 1. Chemical analyses of forages[a]

Item	ADF	Crude Protein	ADF Protein	Available Protein
			Percent	
Rect. bales	37.3^{b}	12.9^{b}	1.8^{c}	11.1^{b}
Hay stacks	38.9^{c}	11.9^{b}	2.7^{b}	9.2^{c}
Loose rounds	39.9^{c}	11.0^{c}	3.1	7.9^{d}
Tied rounds	39.2^{c}	$11.3^{b,c}$	2.8^{b}	$8.5^{c,d}$
Cornstalks	54.1^{d}	5.1^{d}	0.9^{e}	4.2^{e}
Cornstalks + NH_3	54.2^{d}	6.2^{d}	1.6^{c}	4.6^{e}

[a]Dry matter basis.

[b,c,d,e]Means in same column with different superscripts were significantly different ($P < .05$).

Mean subjective quality scores were significantly different for rectangular bales, hay stacks and cornstalk stacks (Table 2). However, quality scores for either type of large round hay bale were less ($P < .05$) than mean scores for rectangular bales or ammonia-treated cornstalk stacks. Quality score primarily reflects discoloration and mold. Also presented in Table 2 are the amounts of dry matter offered, refused, and consumed (obtained by difference), and the relative percent of dry matter offered with rectangular bales equaling 100%. The completeness with which refused hay was recovered and measured is questionable, because hay pulled out of the racks and trampled was not entirely recoverable. However, these results indicate that 20% more hay dry matter is required for hay stacks, 32% more for non-tied round bales, and 21% more for string-tied round bales compared to the amount of hay required in a rectangular, barn-stored bale system. A larger proportion of the large hay packages had deteriorated to the extent that the cows refused more of the forage. This greater refusal required that more total forage dry weight be offered.

Cows receiving rectangular or tied round bales were ($P < .01$) fatter at the end of the trial than were cows receiving cornstalks (Table 3). However, there was no significant difference in the mean condition scores of cows receiving outside-stored large hay packages. Lactating cows receiving rectangular hay bales essentially maintained their own weight through the trial, gaining an average of 9.5 kg. Groups fed non-tied round bales or either of the two cornstalk treatments lost more ($P < .01$) weight than any other group. The ranking of pregnant and lactating cows by treatments was essentially the same. These results indicate that although cows were fed the outside-stored non-tied round bales and cornstalk treatments *ad libitum*, their performance was appreciably less than performance of cows fed rectangular bales on a restricted basis.

TABLE 2. Means from feeding trial[a]

Item	% D.M.	Quality Score[b]	D.M. Offered (head/day)	D.M. Refused (head/day)	D.M. Consumed (head/day)	D.M. Offered (%)
Rect. bales	84	6.8[c]	10.6	1.7	8.9	100
Hay stacks	78	5.8[c,d]	12.8	3.1	9.6	120
Loose rounds	71	4.5[d]	14.1	3.7	10.4	132
Tied rounds	75	4.2[d]	12.9	3.1	9.8	121
Cornstalks	76	5.7[c,d]	17.7	6.8	10.9	167
Cornstalks + NH_3	80	6.8[c]	18.2	6.7	11.5	171

[a]D.M. basis; 10 cows/treatment.
[b]Higher score equals higher quality (range 1 to 10).
[c,d]Means in same column with different superscripts were significantly different ($P < .05$); only quality score subjected to analysis.
[e]Rectangular bales assigned value of 100%.

TABLE 3. Means from feeding trial

Item	No. Cows[a]	Condition Score[b]	Weight Change[c] Pregnant	Weight Change[c] Lactating
Rect. bales	10	12.6[d]	+58.6[d]	9.5[d]
Hay stacks	10	10.8[e,f]	+31.3[e]	−33.1[e]
Loose rounds	10	10.4[e,f]	+3.6[f]	−66.3[f]
Tied rounds	9	11.4[d,e]	+21.8[e]	−34.0[e]
Cornstalks	8	9.9[f]	+4.5[f]	−76.3[f]
Cornstalks + NH_3	10	9.8[f]	+4.5[f]	−84.0[f]

[a]Two cows in the cornstalk treatment and one cow in the tied round bale expired after calving in April period of inclement weather.
[b]Higher score equals more fatness (range 1 to 17).
[c]Within each group approximately half of the cows had calved.
[d-f]Means in same column with different superscripts were significantly different ($P < .01$).

Two cows in the non-treated cornstalk treatment and one cow in the tied round bale treatment died within ten days after calving, during a period of extremely low temperatures, high winds, and snow. Performance of these cows to time of death was included in the mean final performance (Table 3). The cows that died were generally the poorest performing cows within their respective lots.

Calves born to these cows near the end of the wintering trial were maintained with the cows on pasture throughout the grazing season. Mean 205-day calf weight was not significantly affected by the wintering treatment.

Trial II

A summary of the measured losses for non-treated and treated rectangular bales (barn-stored) and string-tied round bales and stacks (outside-stored) is presented in Table 4. Field loss before baling was the difference between standing yield and windrow yield at the time of baling. There was a 6.1% greater field loss for non-treated hay, primarily because of increased exposure through field curing (Table 4). Baling losses were obtained by yield in the windrow compared with the amount of hay actually packaged, and were similar for non-treated and treated rectangular bales and round bales, although a 6.6% greater loss was obtained with non-treated stacks. There also was a greater difference in storage losses for stacks than for round or rectangular bales. Feeding losses for treated hay ranged from 0.4% for rectangular bales to 5.5% for the large hay packages, and for non-treated hay 5.2% for the rectangular bales to 18.3% for the stacks. Chemical treatment reduced total dry matter losses by 14.9, 17.7, and

TABLE 4. Effects of chemical treatment and package type on dry matter losses[a]

Item	Rect. Bales None	Rect. Bales Chemical	Round Bales None	Round Bales Chemical	Stacks None	Stacks Chemical
			Percent			
Field loss	13.2	7.1	13.2	7.1	13.2	7.1
D.M. baling	83.0	72.8	84.0	75.5	85.0	72.6
Baling losses	3.5	2.6	10.2	9.1	13.4	6.8
Storage losses	7.8	4.8	11.7	10.1	16.6	11.3
Feeding losses	5.2	0.4	14.3	5.5	16.3	5.5
Total losses	29.7	14.8	49.4	31.7	59.5	30.6

[a]Rectangular bales stored inside; round bales and stacks stored outside.

TABLE 5. Results of brood cow trial[a]

Item	Rect. Bales		Round Bales		Stacks	
	Field Cured	Chem. Trt.	Field Cured	Chem. Trt.	Field Cured	Chem. Trt.
Wt. gain (kg)	35.3[b]	30.3[c]	34.4[b]	32.5[c]	28.3[c]	37.7[b]
D.M. consumed/offered	94.6	99.4	85.5	93.5	84.7	94.3
Kg hay/kg gain	25.7	27.7	32.4	30.5	40.4	32.1

[a]18-day acceptability trial; rectangular bales stored inside; round bales and stacks stored outside.
[b,c]Means in same row with different superscripts were significantly different ($P < .05$).

28.9% for rectangular bales, round bales, and hay stacks, respectively. There were no significant differences in ADF, crude protein, ADF-protein, or available protein; thus these results are not presented. One reason for the lesser importance of package type differences on chemical analyses than observed in Trial I, was that hard rains occurred soon after baling Trial I hay, and because Trial II feeding study was conducted three months before the Trial I study, thereby reducing the weathering time of hay used in Trial II.

Weight gain within the rectangular and round bale groups was less ($P < .05$) for chemically-treated than for non-treated groups (Table 5). However, within hay stack groups, cows fed chemically-treated hay gained significantly more ($P < .05$) than cows receiving non-treated hay. The percent of hay offered that was actually consumed favored the chemically-treated hay. This trial was of short duration, and the results are preliminary. However, particularly with regard to field loss, baling loss, feeding loss, and amount of hay required per unit of weight gain, chemical treatment appears to have definite possibilities. Perhaps the most important parameter from this trial is that approximately 30% of the standing forage was lost in harvesting, storing, and feeding rectangular bales, which was the least wasteful non-treated system tested.

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DISCUSSION

Unidentified. Can you explain why the protein was consistently lower in the loose round bales?

Wilson. This was probably due to leaching of nutrients. Crude protein content would include that part of the protein which was made unavailable by heating or molding, and so this is not a loss factor.

F. P. Horn (Oklahoma, USA). We tried to use anhydrous ammonia in some of our work and found this to be a serious health hazard. Has this been a problem?

Wilson. This has been a problem and needs to be watched carefully. However, last year in Pennsylvania we had about 90 farmers applying anhydrous ammonia to corn silage under a USDA-supervised program and had no trouble. Of course, that's a different situation than having a field application such as we were using with the flail one-ton stacker.

Unidentified. You might comment that the ammonia was applied through the cold flow system and the previous questioner may have used ammonia vapors.

Wilson. Yes. The cold flow system appears to be safer than other types of application.

109.

Synchronized Estrus and Use of Artificial Insemination in Small Herds of Beef Cattle*

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The cattle industry of the United States is currently involved in an extremely tight cost-price squeeze. Available evidence indicates that costs are going to continue to increase and that returns are going to fluctuate. These fluctuations have been extremely wide over the past few years and are expected to continue. Under such economic conditions, owners of small beef herds (the average herd size in the U.S. is less than 20 cows) have particularly high relative risks, especially on marginal hill lands. The only protection a producer using a cow-calf system has against the cost-price squeeze is to improve management and to use an improved breeding program, aimed at higher weights of calf produced per cow bred.

A successful program of artificial insemination (AI) must always include careful management. With a well-planned AI program, better breeding stock can be secured to improve the breeding program. Through the efficient use of AI, heavier calves at weaning time will result and gross return will be improved. Also, heifers of greater genetic merit will be available for replacement purposes.

The object of this paper is to evaluate the use of exogenous prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) as a tool for operating an AI program with synchronization of estrus and to evaluate the economics of using AI versus conventional breeding in efforts to improve production in small herds of commercial beef cattle. $PGF_{2\alpha}$ is a naturally occurring luteolysin in cattle and is produced by the uterine endometrium (Hansel *et al.*, 1976).

$PGF_{2\alpha}$ has been used over the past three years in field trials in West Virginia under various management conditions. In these trials, additional treatment with estradiol benzoate as a means to synchronize release of LH and increase the precision of synchronization of estrus has also been evaluated. Based on the results of these trials, synchronization of estrus, using $PGF_{2\alpha}$ and estradiol benzoate, is a tool that can make it feasible for beef cattlemen to use AI. The real question to be asked concerning the use of prostaglandin and AI is whether or not improved calf weights and quality can more than offset the increased costs incurred.

SYNCHRONIZATION OF ESTRUS WITH $PGF_{2\alpha}$

A summary of estrous response obtained during three years of West Virginia studies using $PGF_{2\alpha}$ with and without estrogen (both administered intramuscularly) is found in Table 1. These data are summarized over a number of different treatment regimens, each designed to test a particular area of interest concerning response to $PGF_{2\alpha}$. No significant differences between the treatment sequences were observed, therefore the data pooled over all treatments are presented. $PGF_{2\alpha}$ injections, followed by estradiol benzoate at 40 to 48 hours, consistently resulted in a higher percentage of treated animals showing estrus than was seen with $PGF_{2\alpha}$ alone.

TABLE 1. Overall estrous response to $PGF_{2\alpha}$ with and without estradiol benzoate[a]

Status	Treatment	Number of Animals: Treated	Number of Animals: In estrus	Percent In estrus
Lactating cows	No. E_2B	248	166	67
	E_2B	190	171	90[b]
Heifers	No E_2B	85	65	76
	E_2B	82	75	91[b]
Dry cows	No E_2B	18	16	89
	E_2B	15	14	93

[a]400 mg IM 40–48 hrs after $PGF_{2\alpha}$.
[b]$P < .05$ compared to no E_2B.

Conception and pregnancy rates are reported in Table 2 for the treatment sequence upon which the economic analyses to be presented here are based. The recommended treatment consists of two injections of prostaglandin 10 to 12 days apart (Cooper, 1974; Lauderdale, 1975; Hafs *et al.*, 1976) followed 40 to 48 hr later by 400 mg estradiol benzoate (Welch *et al.*, 1975; Peters *et al.*, 1976). Conception rate is defined as the percentage of cows exhibiting estrus that delivered a calf from AI; pregnancy rate as the percentage of treated cows that delivered an AI calf. Conception rates varied from 44 to 50% and pregnancy rates from 34 to 45% in these trials. In general,

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TABLE 2. Effects of number of treatments with $PGF_{2\alpha}$ and of estradiol benzoate on synchronization of estrus in beef cows and heifers

Number of Treatments with $PGF_{2\alpha}$	Estradiol Benzoate?	No. of Animals	Rate (%) of Synchronization	Rate (%) of Conception	Rate (%) of Pregnancy
1	No	144	75	46	34
	Yes	101	92[b]	49	45
2[a]	No	190	67	50	34
	Yes	169	89[b]	44	38

[a]Twelve days apart.
[b]$P < .05$ compared to no estradiol benzoate.

pregnancy rates for estrogen-treated animals exceeded those for non-estrogen treated animals (45 versus 34% and 38 versus 34% for one and two prostaglandin injections, respectively). This was due to the fact that more estrogen-treated animals exhibited estrus during the target period. These data were based on only one insemination. Some of the herds in these treatments yielded pregnancy rates as high as 100% while others were as low as 0%. These differences reflect the large differences in overall management ability of the cooperating farmers.

COSTS

The bull costs for producing a calf in three different herd sizes, 10, 20, and 30 cows, are estimated in Tables 3, 4, and 5. The figures used to calculate bull costs for natural service (Table 3) were derived from the average sale prices of performance-tested bulls and the average of the top 10% of these bulls at the Wardensville, West Virginia, Bull Test facility for the years 1972-76.[1] Included in the total bull costs were the costs for maintaining the bull. The cost items included were comparable to recently published figures (Singleton and Petritz, 1976; Herrick, 1976) as were the results obtained (Table 5.). Herrick quoted figures from Daryl Strohbein of Iowa State University, who calculated that an average bull (initial cost $750) cost $12.03 per cow serviced in a 30-cow herd while a superior bull (initial cost $1,200) cost $18.20 per cow serviced. Singleton and Petritz (1976) presented an annual cost of $413.50 for owning a bull which cost $1,000 initially. For a 30-cow herd the cost per cow would be $13.78 compared to $16.11 for average bulls in the present study.

The estimated breeding costs involved in the control of estrus and ovulation with $PGF_{2\alpha}$ and

[1]Data courtesy of B. W. Wamsley, Jr., West Virginia University Livestock Extension Specialist.

TABLE 3. Total annual costs of ownership of average and superior performance-tested bulls

Item	Average bull	Top 10% of Bulls
Depreciation	$147.00[a]	$280.00[b]
Interest at 8%	53.04	100.88
Hay	165.00	165.00
Pasture	24.00	24.00
Minerals	1.25	1.25
Veterinary and medical	12.00	12.00
Corral, housing	25.00	25.00
Purchase expenses	20.00	20.00
Insurance	10.00	15.00
Labor	25.00	25.00
Taxes	1.00	1.00
Total	$483.29	$670.13

[a]Based on the average price of performance-tested bulls at the Wardensville, W.Va., performance-tested bull auction for the five years, 1972-76 ($885.00) and a salvage value of $500.00 after use of the bull for three years.
[b]Based on the average price of the top 10% of performance-tested bulls at Wardensville for the five years, 1972-76 ($1,680.00) and a salvage value of $800.00 after three years.

TABLE 4. Breeding costs per calf raised from an AI program using $PGF_{2\alpha}$[a]

Item	First Service Conception Rate 40%	First Service Conception Rate 60%
Services per conception	1.88[b]	1.65[b]
Semen cost @ $6.00 per unit ($)	11.28	9.90
Technician cost per service ($)	6.00	6.00
Total technician cost ($)	11.28	9.90
Labor cost per calf ($)		
Cows/herd		
10	10.29	8.82
20	5.29	4.41
30	3.53	2.94

[a]Drug cost not included as $PGF_{2\alpha}$ is not yet on the market.
[b]Assuming an 85% calf crop with two inseminations only.

TABLE 5. Bull costs per cow ($)

Herd Size	Natural Mating: Average Bull	Natural Mating: Top 10% Bull	AI: 40%[a]	AI: 60%[a]
10	48.32	67.01	27.92	24.83
20	24.16	33.50	23.67	20.58
30	16.11	22.34	22.18	19.33

[a]Conception to first service.

TABLE 6. Production and income data per 100 cows

Item	Natural Mating				AI	
	Average Bulls		Top Bulls			
	Straightbred	Crossbred	Straightbred	Crossbred	Straightbred	Crossbred
No. calves raised	92	92	92	92	85	85
Heifers to sell	31	31	31	31	24	24
Steers to sell	46	46	46	46	42	42
Avg. wt. heifers sold (kg)	176	199	190	212	194	217
Avg. wt. steers sold (kg)	189	212	203	225	207	230
Price of heifers[a]	$ 55.56	$ 57.23	$ 57.20	$ 60.71	$ 57.36	$ 60.58
Price of steers[a]	$ 77.22	$ 81.50	$ 79.27	$ 83.50	$ 81.69	$ 83.77
Value of heifers	$ 3,031.05	$ 3,530.28	$ 3,369.08	$ 3,989.70	$ 2,670.72	$ 3,154.80
Value of steers	$ 6,713.70	$ 7,948.34	$ 7,402.32	$ 8,641.84	$ 7,101.78	$ 8,091.72
Total value-calves	$ 9,744.75	$11,478.62	$10,771.40	$12,631.54	$ 9,772.50	$11,246.52
Cull cows sold	12	12	12	12	15	15
Wt./cow (kg)	454	454	454	454	454	454
Price of cull cows[b]	$ 55.06	$ 55.06	$ 55.06	$ 55.06	$ 55.06	$ 55.06
Value of cull cows	$ 3,000.00	$ 3,000.00	$ 3,000.00	$ 3,000.00	$ 3,750.00	$ 3,750.00
Total value	$12,744.75	$14,478.62	$13,771.40	$15,631.54	$13,522.50	$14,996.52
Gross return/cow	$ 127.45	$ 144.79	$ 137.71	$ 156.32	$ 135.22	$ 149.97

[a]Based on average 1975 prices per hundred kg. for these weights of calves at West Virginia Feeder Calf Sales; data courtesy of J. C. Emch, West Virginia University Extension Livestock Specialist.
[b]Price per hundred kg.

estradiol benzoate and utilization of AI are presented in Table 4. These costs were calculated for a first service pregnancy rate of either 40% or 60% and adjusted for a total calf crop of 85%. The assumption was made that with services at two estrous periods in the herd, whether first service conception rate was 40 or 60%, an 85% calf crop would be expected. These estimates assume adequate management conditions for a good AI program. AI is not apt to be economical at any cost if a calf crop of at least 85% cannot be attained. With a West Virginia average calf crop in 1975 of 88% the average beef cow cost the farmer an estimated 58% more than she earned (Emch and Wamsley, 1976).

Bull costs per cow with both natural service and AI are summarized in Table 5. From these estimates alone, AI would be the most economical method of breeding in the 10-cow herd and, if first service conception were at least 60%, in the 20-cow herd as well. At this point, only costs have been taken into account and production differences due to size of calf crop, increased weaning weight of calves, or improved quality in heifer calves have not been considered. These estimates do not include any drug costs for the $PGF_{2\alpha}$ or estradiol benzoate. On this same bull cost basis, AI would be more economical in all three herd sizes than using a bull from the top 10% of the performance-tested bulls.

Gross returns per cow in a herd of 100 cows are estimated in Table 6. Prices utilized for calculating returns were averages of prices received by farmers at West Virginia feeder calf sales in 1975. Calf weights utilized in calculating returns were based on (1) 1975 state averages, (2) the use of bulls currently available in AI studs for AI and the designated performance-tested bulls for natural mating, and (3) average performance differences obtained in AI and crossbreeding programs on farms in the Allegheny Highlands Project over the four-year period, 1972–75. A 92% calf crop for natural service and an 85% calf crop from AI were assumed. Using these estimates and the bull costs per cow, economic comparisons of AI and natural mating are made in Table 7. These estimates of returns do not consider the higher value of replacement heifers produced by AI. This value has been estimated to be from $15 per head (Singleton and Petritz, 1976) to as much as $26.40 per head (Herrick, 1976). Certainly it will vary considerably among the bulls used in either AI or natural service.

DISCUSSION

Economically, AI is advantageous or at least feasible in 10- and 20-cow herds only as long as the cost of $PGF_{2\alpha}$ does not exceed $3.48 when a 40% conception rate to crossbreeding is obtained. In a crossbreeding program, AI has an advantage because of the availability of semen from bulls of any breed chosen to be used in the program. In 30-cow herds the best breeding system, based on the economic predictions in this study, is cross-breeding with natural service to an average performance-tested bull.

TABLE 7. Gross return ($) per cow minus bull cost for each kind of mating and breeding system in 10-, 20- and 30-cow herds and advantage for AI ($) over most economic natural mating

Variable	Herd Size 10		20		30	
Mating system[a]	S	C	S	C	S	C
Gross return less bull cost						
Natural mating						
Average bull	79.13	96.47	103.29	120.63	111.34	128.68
Top bull	70.70	89.31	104.27	122.82	115.37	133.98
Artificial insemination						
40%[b]	107.30	122.05	111.55	126.30	113.04	127.79
60%[b]	110.39	125.14	114.64	129.39	115.89	130.64
Advantage of AI over best natural mating system						
40%[b]	28.17	25.58	7.34	3.48	−2.33	−6.19
60%[b]	31.26	28.67	10.43	6.57	0.52	−3.34

[a]S = straightbred, C = crossbred.
[b]Conception rates.

However, with this method there are problems with maintaining a breeding system. For example, replacement heifers of a particular breed or cross may be difficult to purchase and costs may be increased. Utilizing one bull to produce replacement heifers and another bull to complete the crossbreeding system would increase costs to the point that AI would again become the more economical method of breeding.

If the increased value of $15 per replacement heifer from AI (Singleton and Petritz, 1976) were included in these estimates, natural mating to an average bull could not be justified economically in any of the herd sizes studied. From a practical standpoint, however, if herd management is poor, then AI cannot be recommended!

With good herd management conditions, an AI program can be economically justified. The use of a synchronization program with $PGF_{2\alpha}$ alleviates some of the labor cost of AI in beef cattle on pasture, a cost which has been excessive in the past, especially in hill country. Under better management conditions, conception rates are improved, calf crop percentage is improved, and AI can provide many advantages in addition to direct economic ones. AI programs should improve overall management of the herd, because the cows must be observed more closely and more often by the producer.

The data presented have been based on averages for each input and output factor. No consideration has been given to improvements over time as a result of experience with an AI program or selection for conception rate to first service (Inskeep *et al.*, 1961). If top-performing bulls were selected and a well-designed crossbreeding system were used in an AI program, then the economic advantages could be enhanced.

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DISCUSSION

L. Ainsworth (Ottawa, Canada). What was the target period that you used for establishing the percentage of cows in estrus?

Peters. Prostaglandin $F_{2\alpha}$ injected on day 0, followed by estradiol benzoate 40–48 hours later. The average time for animals coming back in heat is 66–67 hours after $PGF_{2\alpha}$. We check heat over a period of 3–5 day, depending on the particular experiment, but the target period for the data reported was 54 to 84 hours after $PGF_{2\alpha}$.

Ainsworth. You said that your pregnancy diagnosis or conception rates were 38–44% to the synchronized estrus, and you made a statement of 85% total conception rate a follow-up breeding at second estrus. Is that what you expected or what you actually achieved?

Peters. That is what we expected. We have bred at the second heat in only one herd. In that herd total conception after two heat periods was 88%. There are reports in the literature indicating that type of response. In this project the results will vary greatly and will depend a great deal on the type of management. With poor management, we may examine 100 cows and find only 20 cycling; so in some herds we may get pregnancy rates near 0%. In other herds, with good management, we may get a high percentage of cows cycling and 80–100% first service conception rate. Management is the key to AI programs.

110.
Incidence and Methods of Preventing Grass Tetany*

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Grass tetany is a common problem in many areas throughout the world. It is an old problem resulting primarily from inadequate magnesium in older, lactating beef cows. The term "grass tetany" is commonly used to characterize the syndrome because a high percentage of the incidence occurs on short green grass during the transition period from winter to spring feeding. It appears that the incidence is higher on improved hill land pastures with high levels of fertilizer applied.

OBJECTIVES

1. To determine the incidence of grass tetany under a conventional management system.
2. To evaluate methods of supplying supplemental magnesium.

PROCEDURE

Four experiments (1973–74–75–76) were conducted using a combination of Angus, Milking Shorthorn, Holstein-Angus crossbreds, and crossbred heifers (C × A, C × MS-A, A × H). The cows ranged in age from 6 to 12 years. The heifers averaged 12 months of age when blood samples were taken.

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Experiment 1

This study was divided into four phases.

Phase 1: Fifty-six dry pregnant beef cows (19 Milking Shorthorn and 37 Angus ranging in age from 5 to 10 years) were in one group grazing on aftermath [(fescue *Festuca arundinacea* Schreb.), orchardgrass (*Dactylis glomerta* L.), and clover (*Trifolium* sp.)] from 9/28/73 through 1/30/74. Free-choice (FC) mineral containing 14% magnesium oxide was provided and mixed grass-clover hay was fed when needed.

Phase 2: On 1/30/74, cows were weighed and allotted within breed and age groups into two groups. Both had access to some pasture, *ad lib* hay (mixed grass-clover), and protein blocks. Group 1 was fed an additional 2.2 kg of ground ear corn daily per cow. Phase 2 was terminated on 3/28/74.

Phase 3: At the end of phase 2, each cow was weighed, urine samples collected, and blood samples drawn. Blood serum was analyzed for magnesium, and cows within each previous treatment were allotted on the basis of serum magnesium levels into four groups. On 4/4/74 the following treatments were assigned to the groups: *Group 1*—hay and FC mineral without supplemental magnesium; *Group 2*—hay, protein blocks containing 2.5% Mg and FC mineral without magnesium; *Group 3*—hay, 2.2 kg

ground ear corn plus 56 g of magnesium oxide and FC minerals without magnesium; and *Group 4*—hay and FC mineral consisting of equal parts corn, magnesium oxide, trace mineralized (TM) salt, and bonemeal. Phase 3 was terminated on 4/25/75.

Phase 4: All treatment groups in phase 3 were combined into one group on 4/25 and grazed on pasture (grass-clover mixture) through 5/15/75. A free-choice mineral mixture was provided consisting of equal parts corn, magnesium oxide, TM salt, and bonemeal.

Each cow was weighed and blood and urine samples taken on 11/21/73, 1/30, 3/28, 4/11, 4/25, and 5/15/74. The blood serum was analyzed for Ca, P, Mg, K, and Zn. Urine was analyzed for creatinine and magnesium.

Experiment 2

Crossbred heifers weaned on 9/28 were fed 2.7 kg of ground ear corn on pasture. On 12/27/73, the heifers were allotted on the basis of weight within breed into three groups of 41 each. The treatments assigned were as follows: *Group 1*—pasture aftermath, hay, and FC mineral containing 14% magnesium oxide; *Group 2*—same as group 1 plus 1.3 kg of ground ear corn per head daily; and *Group 3*—same as group 1 plus 2.7 kg of ground ear corn per head daily. These heifers were continued on these treatments through 4/15/74. Liveweights were taken on 12/27/73 and 4/15/75. Blood samples were taken from 15 heifers from each group on 3/26/74. Blood serum was analyzed for Mg, P, Ca, K, and Zn.

Experiment 3

Forty-eight dry pregnant beef cows (34 Angus, 9 Milking Shorthorn, and 6 crossbreds—¼ Holstein × ¼ Red Dane × ½ Angus) were allotted within breed and age into three groups of 16 cows each. The treatments assigned to each group were as follows: *Group 1*—negative control, no supplemental magnesium; *Group 2*—free-choice mineral consisting of equal parts TM salt, bonemeal, magnesium oxide, and ground corn; and *Group 3*—liquid urea supplement (National Molasses Mol-Mix 32-003) in a lick tank. Each group of cows was assigned to a pasture paddock of approximately 10 ha. The pasture mixture consisted of fescue, orchardgrass, and clover.

The study started on 12/4/74 and continued through 5/15/75. Hay was fed when needed during the gestation period. The 60-day calving period started on 2/15. During the lactation period hay, ground ear corn, and protein blocks without magnesium were fed *ad lib*, 2.2 kg/day and *ad lib* respectively. The liquid supplement consumption for group 3 was measured weekly. Each cow was weighed and blood sample taken and urine sample collected on 12/4/74, 1/30, 3/6, 3/27, 4/10, 4/24, and 5/15/75. The blood serum was analyzed for Mg, Ca, K, P, and Zn. The pH, magnesium, and creatinine values were determined on the urine.

Experiment 4

A total of 55 cows (31 Angus, 3 Shorthorn and 21 Angus × Shorthorn) was divided within breed into three groups. Each group was assigned to a 10 ha pasture (grass-clover mixture). These cows were maintained in these pastures from 12/2/75 through 4/27/76. During the pregnant, nonlactating period (12/2/75–2/3/76), the cows in all three groups had access to the pasture grass aftermath and FC mineral mixtures which were the treatments tested. Beginning on 2/3/76 protein blocks (Farmer's Friend, 37% protein) and big bale hay were provided to all three groups *ad libitum*. Ground ear corn (2.2 kg) was fed per head per day in all groups beginning on 3/2/76.

The treatments were as follows:

Group 1—Negative control, mineral mixture of 2 parts bonemeal and 1 part trace-mineralized salt;

Group 2—2 parts bonemeal, 1 part MgO, and 1 part trace-mineralized salt;

Group 3—1 part bonemeal, 1 part MgO, 1 part trace-mineralized salt, and 1 part ground ear corn.

The cows were weighed and blood samples taken on 12/2/75, 2/3, 3/2, 4/1, and 4/27/76. The blood serum was analyzed for Mg, Ca, P, K and Zn.

The cows showing signs of grass tetany were treated with the following solution: CAL-D-MAG (Pfizer), and the solution contained 23% calcium gluconate, 25% dextrose, 4.5% magnesium oxide, and 1.0% phosphorus.

The magnesium content of the feedstuffs used is presented in Table 1.

RESULTS AND DISCUSSION

The results of experiment 1 by phases are given in Tables 2, 3, 4 and 5. A significant drop in serum magnesium (Table 2) occurred from 11/11 to 1/31 (2.03 vs 1.75 mg%). The level continued to decline through 3/28 to a level of 1.05 mg% (average of the high and low energy groups). Supplemental corn had only slight effect on blood magnesium level (Table 3). No incidence of grass tetany occurred during the first phase. However, during phase 2 (1/30–3/28), two cows receiving high energy (2.2 kg corn) and four cows receiving the low energy diet showed signs of grass tetany (Table 3).

The urine magnesium level decreased markedly (0.519 to 0.027 mg/mg creatinine) and remained at a low level through phase 2. The data indicate that the magnesium levels in the ration ingredients

TABLE 1. Magnesium content of feeds for Experiments 1, 2, 3, and 4, 1973–76 (dry matter basis)

Feed	Magnesium (%)
Experiment 1, 1973–74	
Hay (grass-clover)	0.10
Ground ear corn	0.05
Protein blocks with Mg	2.65
Protein blocks without Mg	0.36
Experiment 2, 1973–74	
Hay (grass-clover)	0.09
Ground ear corn	0.05
Experiment 3, 1974–75	
Hay (grass-clover)	
(a) sampled, 12/12/74	0.18
(b) sampled, 3/27/74	0.14
Ground ear corn	0.10
Protein blocks	0.34
Trace mineralized salt	0.006
Bonemeal	0.31
Experiment 4, 1975–76	
Hay (grass-clover)	0.08
Ground ear corn	0.09
Protein block	1.50

TABLE 2. Serum electrolytes and urine magnesium, Experiment 1, Phase 1, 9/28/73–1/31/74

Bleeding	Serum Electrolytes (mg%) Mg*	Ca*	P*	K	Urine Mg mg/mg Creatinine
Initial, 11/21/73	2.03	10.8	6.0	23.0	0.519
Final, 1/31/74	1.75	12.3	5.5	21.9	0.027

*Mean values are significantly different ($P < .05$).

were not adequate to maintain normal magnesium blood values.

During the repletion phase (4/4 to 4/25, phase 3), the feeding of 2.2 kg of ground ear corn plus 56 g of MgO per head per day was the most effective method in elevating the serum magnesium above 2 mg% within a three-week period after the cows had been depleted (Table 4). The feeding of FC mineral with MgO and corn was almost as effective; however, the feeding of protein blocks with 2.5% Mg or hay was ineffective in elevating the serum magnesium to normal levels within a three-week period. The intake of the protein block was 0.1 kg per head per day. The amount of hay eaten was minimal.

TABLE 4. Serum and urine magnesium, Experiment 1, Phase 3, 3/28/74–4/25/74, 28 days

Treatment	Blood Sampling Date 3/28/74	4/11/74	4/25/74
Serum Magnesium (mg%)			
1. No supplemental Mg	1.15	1.05	1.25
2. Protein blocks, 2.5% Mg	1.03	1.22	1.43
3. Corn, with 2 oz MgO	1.03	1.68	2.11
4. Free-choice min 25% MgO	0.98	1.27	1.92
Urine Magnesium (mg/mg Creatinine)			
1. No supplemental Mg	0.036	0.042	0.074
2. Protein blocks, 2.5% Mg	0.016	0.018	0.074
3. Corn, with 2 oz MgO	0.035	0.226	0.259
4. Free-choice min 25% MgO	0.056	0.071	0.162

Urine magnesium showed a significant increase in the group receiving corn and 56 g MgO and a slight increase in the group receiving FC mineral with MgO and corn (Table 4).

During phase 4 (4/25–5/9) experiment 1, when cows were receiving adequate green pasture, the serum magnesium levels decreased in the groups that had been on corn plus 56 g MgO and FC mineral with MgO. The other two previous treatment groups in phase 3 showed higher serum Mg levels (Table 5). Urine magnesium levels decreased markedly from the beginning to the end of phase 4 (Table 5).

When yearling heifers were fed similarly to the older cows in experiment 1, no effect ($P > .05$) was observed on serum magnesium (Table 6).

In experiment 3 (Table 7), the serum magnesium values for the FC mineral and liquid supplement groups were 2.06 and 2.04 mg%, respectively, on 3/6/75 and both groups were higher ($P < .01$) than the control group. However, the magnesium values for all three groups decreased sharply after 3/6 to a low on 4/10/75 and then increased above 2 mg%

TABLE 3. Serum and urine magnesium, Experiment 1, Phase 2, 1/31/74–3/28/74, 56 days

Treatment	Grass Tetany Incidence	Serum Mg (mg%) 1/31/74	3/28/74	Urine Mg mg/mg Creatinine 1/31/74	3/28/74
High energy	2	1.77	1.15	0.037	0.055
Low energy	4	1.70	0.95	0.024	0.015

TABLE 5. Serum and urine magnesium, Experiment 1, Phase 4, 4/25/74-5/9/74, 14 days

Treatment	Serum Mg (mg%) 4/25/74	Serum Mg (mg%) 5/9/74	Urine Mg mg/mg Creatinine 4/25/74	Urine Mg mg/mg Creatinine 5/9/74
1. No supplemental Mg	1.25	1.62	0.074	0.045
2. Protein blocks, 2.5% Mg	1.43	1.76	0.074	0.047
3. Corn with 2 oz MgO	2.11	1.87	0.259	0.058
4. Free-choice min. 25% MgO	1.92	1.85	0.162	0.046

TABLE 6. Serum magnesium for heifers, Experiment 2, 12/27/73-4/19/74

	Treatment. Ground Ear Corn (kg) 0.0	1.3	2.7
Serum Magnesium (mg%)	1.86	1.96	1.96

in groups receiving FC mineral and liquid supplement, with 1.97 mg% for the negative control on 5/15/75. Urine magnesium values showed a similar pattern to the serum magnesium levels.

Serum magnesium values (experiment 4, Table 8) in all three treatment groups decreased from initial values of 1.74, 1.70, and 1.70 mg% on 12/2/75 to 0.95, 1.12, and 1.00 mg% on 3/3/76 for negative control, FC mineral with Mg and FC mineral with Mg and corn treatments, respectively. From the low values on 3/3, the magnesium levels increased in all three treatments to 1.57, 1.73, and 1.95 mg% on 4/27/76, respectively. Three cows in the negative control group and three cows in the group receiving a FC mineral with Mg and corn showed signs of tetany (Table 9). The incidence of tetany appeared to be more related to the onset of calving and lactation than to the growth of green grass in the spring.

TABLE 7. Serum and urine magnesium, Experiment 3, 12/4/74-5/15/75

Blood Sampling Date	Treatments 1 Control: Serum Mg mg %	Urine Mg mg/mg Creatinine	2 Free Choice Mineral: Serum Mg mg%	Urine Mg mg/mg Creatinine	3 Liquid Supplement: Serum Mg mg%	Urine Mg mg/mg Creatinine
12/4/74[a]	1.38	0.254	1.44	0.213	1.61	0.261
1/30/75[b,c]	1.57	0.082	1.70	0.124	1.97	0.204
3/6/75[b,d]	1.47	0.067	2.06	0.293	2.04	0.195
3/27/75	1.46	0.104	1.67	0.123	1.60	0.048
4/10/75	1.23	0.047	1.35	0.072	1.36	0.088
4/24/75	1.60	0.130	1.63	0.093	1.71	0.097
5/15/75	1.97	0.355	2.07	0.625	2.11	0.546

[a]Serum Mg means differed significantly ($P < .05$).
[b]Serum Mg means differed significantly ($P < .01$).
[c]Urine Mg means differed significantly ($P < .05$).
[d]Urine Mg means differed significantly ($P < .01$).

TABLE 8. Serum magnesium, Experiment 4, 12/2/75-4/27/76, 147 days

Treatment	No. Cows	Blood Sampling Date 12/2/75	2/3/76	3/2/76	4/1/76	4/27/76
			mg%			
1. Negative control	19	1.74	1.21	0.95	1.23	1.57
2. FC mineral (with Mg)	18	1.70	1.70	1.12	1.33	1.73
3. FC mineral (with Mg and corn)	18	1.70	1.41	1.00	1.54	1.95

TABLE 9. Summary of cows showing tetany, Experiment 4, 12/2/75–4/27/76, 147 days

Treatment No.	Cow No.	Breed	Stage of Production	Calving Date	Date of First Signs of Tetany	Days After Calving	Date Last Bleeding	Serum Mg Last Bleeding (mg%)	Animal Treatment	End Result
1	139	A	Lactating	2/6/76	2/24/76	18	2/3/76	0.79	None	Found dead 2/24/76
1	6029	A × S	Lactating	2/13/76	3/31/76	47	4/1/76	1.84	500 cc[a] 4/1/76	Died 4/3/76
1	167	A	Lactating	2/8/76	3/21/76	42	3/2/76	0.30	500 cc[a] 3/21/76	Died 3/21/76
2	---------- None of the cows showed tetany ----------									
3	105	A	Lactating	2/10/76	2/13/76	3	2/3/76	0.80	None	Found dead 2/13/76
3	8200	SH × A	Lactating	2/6/76	—	—	2/3/76	1.08	500 cc[a]	Recovered
3	165	A	Lactating	2/17/76	2/29/76	12	2/3/76	1.00	None	Found dead 2/29/76

[a]Solution was Anchor Caldex which contained Mg, Ca, P, and dextrose.

DISCUSSION

A. W. Pantall (New Zealand). I wasn't sure whether these animals were indoors or on grass. If they're on grass, it's been suggested in New Zealand recently that a toxic fungus may be contributing to grass tetany in a similar way that fungus causes facial eczema. Have you considered this possibility here?

Smith. The animals were outside on pastures. I can't answer your second question, but I believe that we are dealing mainly with a problem of magnesium deficiency. A fungus does seems to be involved in the condition of tall fescue toxicity that we experience, but I think this is a separate problem.

R. Shirley (Florida, USA). I wonder what the level of magnesium in your water might be? It looks as if it might be very low. The reason that I mention this is that in southern Georgia they've had tetany which is responsive to magnesium supplementation. With limited water consumption data, water seems to supply about 1% of the NRC requirement. In Florida we've seen a lot of water analyses and find that the water might supply 10% of the recommendations and we have relatively little tetany. Have you made water analyses?

Smith. No.

111.
Grass Tetany As a Metabolic Problem in the Eastern United States

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Hypomagnesemic tetany has traditionally been a significant problem in beef and dairy herds in the northeast United States. The incidence of tetany in this region is associated primarily with two periods: the classical spring or grass tetany is observed when cattle are consuming new herbage growth in spring; winter tetany occurs in beef cattle maintained on hay or rough grazings through the winter months, and most frequently in the cow's postpartum period. In West Virginia and adjoining states, the winter condition may now be economically more damaging than the spring syndrome. It also is less well understood. Winter tetany appears to be related to the prolonged feeding of mature hay or silage which may or may not be inherently low in magnesium concentration, but the condition is undoubtedly affected by lactation stress and by deficits or imbalances of other forage nutrients, by low energy intakes, and by poorly defined environmental variables—all of which influence the animals' physiological status.

A continuing problem is that of maintaining an accurate estimate of the incidence and severity of animal losses due to hypomagnesemia. It is generally conceded that the incidence of tetany is increasing, although the reasons for this are not well defined. Todd (1967) considered that it may be due to an increase in productivity, both in terms of output from the animal and from pastures. At a symposium held in West Virginia in 1959 (Horvath, 1959), reports of hypomagnesemic tetany appeared to be confined mainly to the northeast, to one or two states on the Pacific Coast, and to an area of "wheat pasture poisoning" in the South. More recent surveys (USDA Grass Tetany Workshop, 1975) indicate that grass tetany now occurs in almost all states; it was concluded in this latter survey that annual losses from tetany in this country may be in the range of 1 to 2% of the grazing animal population and that, in 1972, economic losses were of the order of $70 million. Gross (1973) estimated that the value of dairy and beef cattle lost to grass tetany in 1973 was more than $2 million in Pennsylvania alone. The problem is a sporadic one and major outbreaks appear to be related to abnormal seasonal weather conditions.

Two major alternatives for the prevention of grass tetany are available to farmers: (1) increasing the supply of magnesium through the soil and plant; (2) providing supplementary magnesium to the animal. The success of agronomic approaches to raising the magnesium concentration of plants is related to (a) nature of the soil, (b) level of application and source of magnesium, (c) method of application, i.e., whether top dressed, plowed down, or applied to foliage, (d) species of plant, and (e) environmental conditions. In general, magnesium fertilization is most successful on acid, coarse-textured, or sandy soils; Burns and Allcroft (1967) recommended application of 560 kg MgO/ha on light soils with a pH less than 6.5. Low rates (less than 67 kg Mg/ha) have usually been found to be ineffective. Calcined magnesite (magnesia, MgO) and $MgSO_4$ are more effective sources for grassland than dolomite ($CaCO_3.MgCO_3$), especially on high calcium soils (Wolton, 1963). Since dolomite is less soluble than calcitic limestone, application to acid soils is frequently recommended to provide long-term protection. However, in many of the hill farming areas of West Virginia at the present time, dolomitic limestone is both expensive and difficult to obtain and the economics and effectiveness of this soil amendment practice in such locations must be considered rather dubious.

On heavier soils, or where the pH is over 6.5, dusting or spraying herbage with MgO is a more reliable means of preventing spring tetany, although the practice has met with considerably less acceptance in this country than in Europe. Trials in Ireland (Todd, 1966) showed that dusting pastures with 28–34 kg MgO/ha before grazing raised the dietary magnesium level from 0.16 to 0.31% and provided no problems of palatability. A similar approach developed in Georgia (Wilkinson *et al.*, 1973) involves spraying with a slurry of MgO and bentonite (10% MgO and 1.5% bentonite). It has successfully controlled tetany on tall fescue pastures.

In general, direct supplementation of magnesium in the diet to animals at critical periods has been the more widely accepted practice for control of grass tetany in beef cattle herds on hill farms. Methods of providing supplementary magnesium to

cows have been discussed by Horvath (1972) and Fontenot (1976). A critical feature of this approach is cost. While the incorporation of magnesium into grain supplements or corn silage is an effective method of maintaining the magnesium status of cows, the practice can scarcely be justified in view of the present marginal economic condition of the small beef cow herd. In this situation, methods of supplementation are required which are simple and inexpensive and which insure adequate levels of consumption of magnesium by all animals in the herd.

Major reviews on the subject of grass tetany have appeared during the last few years (Grunes *et al.*, 1970; Grunes, 1973; Jones *et al.*, 1972; Metson, 1974), and we do not propose to reinforce this considerable literature. Rather, a brief discussion will consider recent studies on: (1) magnesium distribution in crops and soils; (2) selection of plants for magnesium concentration and availability; (3) fertilization effects on magnesium concentration and availability; (4) practical methods for the control of grass tetany in beef herds on hill farms in the Appalachian region. The work has, in the main, been performed either in Pennsylvania or West Virginia, or in cooperative projects between the two states.

MAGNESIUM DISTRIBUTION IN CROPS AND SOILS

Earlier studies (Beeson, 1959) showed the occurrence of magnesium-deficient soils generally in the Atlantic and Gulf Coastal plains and in the podzol region of the Northeast. This author stated that "no generalizations can be made concerning soil properties and the occurrence of hypomagnesemia or grass tetany in cattle or sheep." Metson (1974), however, discussed a possible relationship between soil type and the prevalence of grass tetany in New Zealand, and recent reports from Pennsylvania support such an association. Fig. 1 (Jung *et al.*, 1975) summarizes magnesium concentration data for five major forage classes, representing 9000 analyses from 1968–73, as related to geographic distribution in the state.

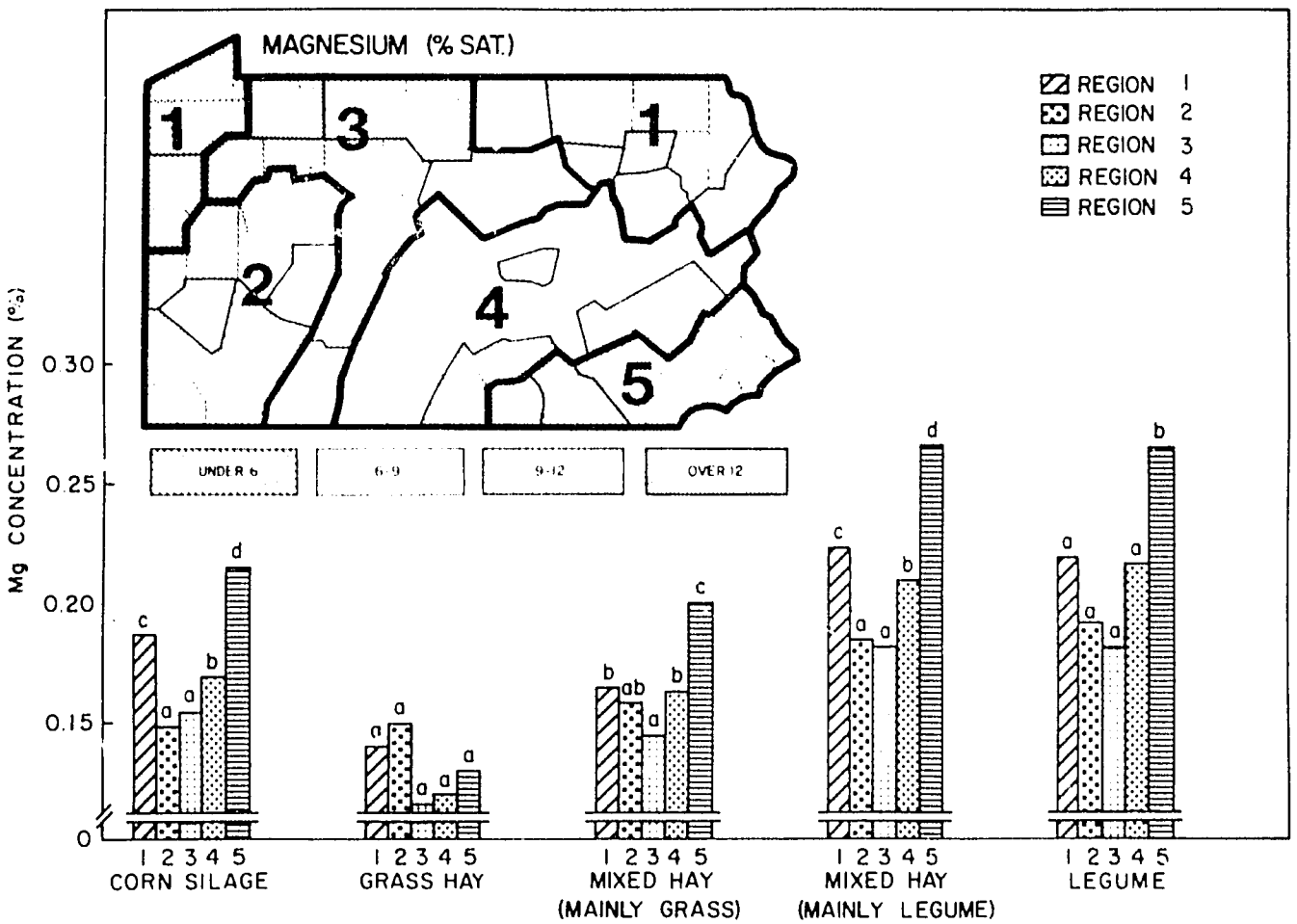

Figure 1. Percent magnesium saturation of cation exchange capacity of soils and magnesium concentrations of forages for five physiographic regions of Pennsylvania. Jung *et al.* (1975). Soil magnesium map by courtesy of W. W. Hinish.

There are significant regional differences in magnesium level for most forage classes and these differences correspond to differences in magnesium concentration of the soil. Magnesium deficient soils are located primarily in the east and west central areas of Pennsylvania and high magnesium soils mainly in southeastern Pennsylvania where, it is claimed, the incidence of grass tetany in cattle is much less common. Data obtained in the Allegheny Highland Project (Baker and Reid, 1976) also indicate a positive correlation between soil and plant magnesium content over a wide range of soils on hill farms in northcentral West Virginia, but show that this relationship may vary with the plant species considered and with years (Table 1). Data from both states confirm that the magnesium concentration of grass species, which represents the major component of diets for cattle on hill farms, is substantially lower than the value of 0.20% which has frequently been accepted as a "safe" level for the prevention of grass tetany (Grunes *et al.*, 1970).

SELECTION OF PLANTS FOR MAGNESIUM CONCENTRATION AND AVAILABILITY

It is well recognized that variability in the mineral concentration of the major forage classes is high, as illustrated by data of Jung *et al.* (1975) in Table 2. Variability of this nature results from soil, climatic and fertilization effects, from industrial contamination, as well as from differences in stage of growth and species of plant. With similar soils and sampling conditions, different plant species can still accumulate significantly different concentrations of minerals. Table 3 provides data on the magnesium concentration of grass, legume, and weed species found commonly in hill pastures in West Virginia (Baker and Reid, 1976). The wide diversity of plant forms and of mineral levels may serve to support an admittedly subjective impression that animals grazing on such pastures may be less subject to mineral disorders than their counterparts maintained on fertilized monocultures of grasses under intensive management systems in the lowlands.

Whether or not this is the case, it is apparent that there is considerable genetic potential for the selection of forage species or cultivars with the ability to accumulate higher levels of magnesium. Hill and Jung (1975) demonstrated a significant variability in mineral concentration between genotypes of Saranac alfalfa (*Medicago sativa* L.) and Hill and Guss (1976) concluded that, with the possible exceptions of timothy (*Phleum pratense* L.) and the *Lolium*

TABLE 1. Correlation coefficients between plant magnesium and soil measurements for five forage species (Baker and Reid, 1976)

Parameters	Alfalfa		Red Clover		White Clover		Orchardgrass		Timothy	
	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972
Soil magnesium	+.60*	+.71*	+.66*	+.64*	+.58*	+.87*	+.32*	+.55*	+.14	+.24
Soil calcium	−.49*	−.67*	−.52*	−.40*	−.55*	−.68*	−.36*	−.26	−.21	−.16
Soil potassium	−.09	−.48*	+.43*	−.17	+.09	+.52*	−.34*	+.19	−.30	−.26
Soil pH	−.34*	−.83*	−.38*	−.11	−.58*	−.85*	−.17	−.04	+.15	+.03

*Values that are significant at 5% level of probability.

TABLE 2. Variability in the mineral composition of farm-grown forages in Pennsylvania, 1968 to 1973, from over 9 000 forage samples (Jung *et al.*, 1975)

	Legume Hay	Legume-Grass Hay	Grass Hay	Corn Silage
		Percent		
Calcium	0.25-2.22	0.22-1.99	0.10-1.13	0.01-1.88
Phosphorus	0.15-0.44	0.08-0.62	0.11-0.37	0.01-0.58
Magnesium	0.10-0.50	0.07-0.56	0.04-0.34	0.01-0.45
		ppm		
Manganese	13-1 080	11-204	13-376	2-267
Iron	41-800	10-2 599	39-500	5-1 500
Copper	4-60	2-92	2-31	1-63
Zinc	12-239	9-357	13-112	3-524

TABLE 3. Magnesium concentration of forage species collected from hill pastures and meadows during two growing seasons in northcentral West Virginia (Baker and Reid, 1976)

Common Name	Scientific Name	%Mg 1971	%Mg 1972
Legumes			
Alfalfa	Medicago sativa L.	0.19	0.20
Alsike clover	Trifolium hybridum L.	0.26	0.36
Crimson clover	Trifolium incarnatum L.	0.24	—
Red clover	Trifolium pratense L.	0.30	0.30
Sweetclover, yellow	Melilotus officinalis (L.) Pall.	0.32	0.39
Vetch, common	Vicia sativa L.	0.16	—
White clover	Trifolium repens L.	0.27	0.26
	Mean	0.25	0.26
Grasses			
Barnyard grass	Echinochloa crusgalli (L.) Beauv.	0.43	0.45
Big bluestem	Andropogon gerardi Vitm.	0.04	0.04
Bluegrass, Ky.	Poa pratensis L.	0.16	0.10
Broomsedge	Andropogon virginicus L.	0.04	0.07
Brome grasses	Bromus sp.	—	0.04
Fescue, red	Festuca rubra L.	—	0.14
Fescue, tall	Festuca arundinacea Schreb.	0.22	0.19
Foxtail	Setaria glauca (L.) Beauv.	0.19	—
Oats	Avena sp.	0.11	—
Orchardgrass	Dactylis glomerata L.	0.19	0.1[illegible]
Panicum	Panicum sp.	0.04	0.11
Poverty grass	Danthonia spicata (L.)Beauv. ex Roem. & Schult.	0.04	0.04
Quackgrass	Agropyron repens (L.) Beauv.	0.10	0.07
Redtop	Agrostis gigantea Roth.	0.12	0.06
Reed canarygrass	Phalaris arundinacea L.	0.21	0.16
Rye	Secale cereale L.	—	0.04
Ryegrass, perennial	Lolium perenne L.	0.21	0.11
Sweet vernal	Anthoxanthum odoratum L.	0.06	0.04
Timothy	Phleum pratense L.	0.08	0.05
Velvet grass	Holcus lanatus L.	0.08	0.09
	Mean	0.16	0.11
Weeds			
Cinquefoil	Potentilla sp.	0.22	—
Dock, curly	Rumex crispus L.	—	0.24
Lambsquarter	Chenopodium album L.	0.96	—
Milkweed	Asclepias syriaca L.	0.50	—
Ragweed	Ambrosia psilostachya DC.	0.53	—
	Mean	0.55	0.24

perenne L × L. *multiflorum* Lam. hybrids, a concentration of 0.20% magnesium was attainable by selection in most forage species. Recent studies by Gross and Jung (unpublished data) at the USDA Pasture Research Laboratory with temperate grasses and legumes grown at three ambient temperatures under greenhouse conditions illustrate further very marked differences between species and cultivars in magnesium concentration (Fig. 2). They found that, in early spring, high magnesium accumulators were Timfor timothy, Nordstern orchardgrass (*Dactylis glomerata* L.), Viking birdsfoot trefoil (*Lotus corniculatus* L.), and Saranac alfalfa, in which the magnesium concentration was approximately twice that of the low-accumulating species. At this growth stage, a difference of 0.15% Mg between timothy cultivars was noted, and a difference of 0.13% between alfalfa cultivars.

It appears, then, to be experimentally feasible to select plants with higher levels of magnesium. The problem, as stated by Cooper (1973), is to define the priority of this approach in relation to the options of increasing plant mineral levels by fertilization or by direct provision of the mineral in the animal's

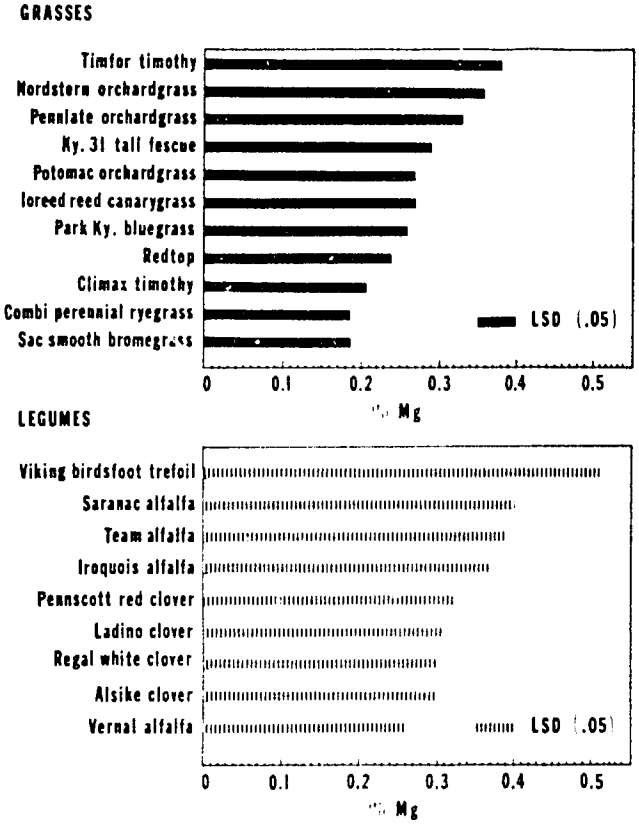

Figure 2. Magnesium concentration in species and cultivars of grasses and legumes grown at cool spring temperatures (12 C, 54 F) under greenhouse conditions. Gross and Jung (unpub. data).

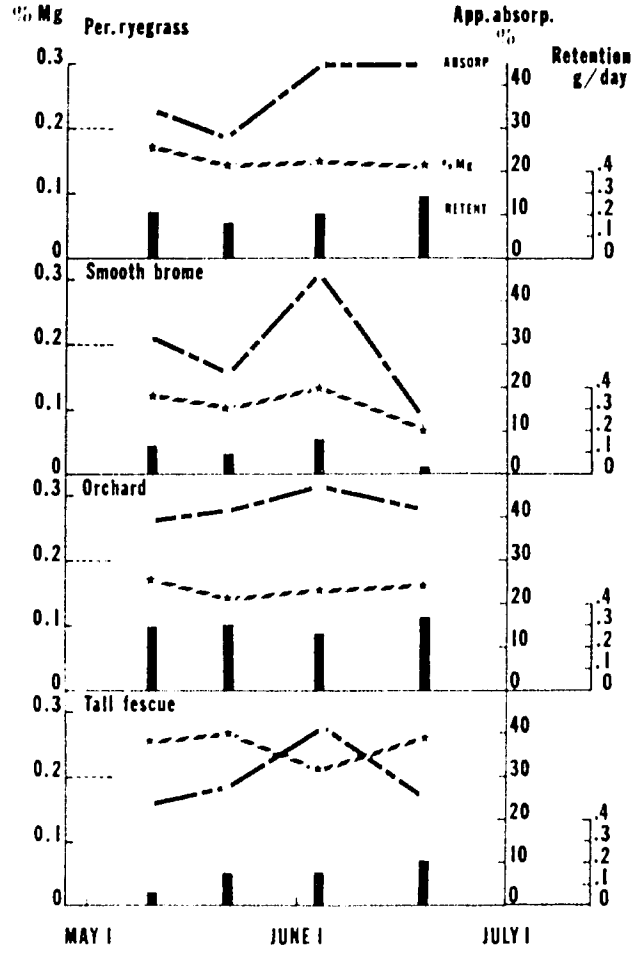

Figure 3. Concentration of magnesium in four perennial grasses at different growth stages as related to apparent absorption (%) and retention (g/day) of magnesium by lambs in balance trials. Concentration of 0.20% Mg in herbage is frequently cited as a "safe" value in the literature.

feed. A further problem would seem to be that of availability. It is implicit in the plant selection approach that plants segregated for higher mineral concentrations will allow also for improved mineral utilization and retention by ruminant animals consuming the plants. That this is not necessarily the case is illustrated in Fig. 3 (Reid, unpublished data). In balance trials with lambs fed cut herbage of four perennial grass species, significant differences in the apparent absorption and retention of magnesium among forages and among growth states were noted. The retention of magnesium by lambs fed tall fescue, with concentrations of magnesium in the range 0.21–0.26%, was, for example, consistently lower than in lambs fed orchardgrass, with magnesium levels in the range of 0.14–0.17%. The data suggest the need for incorporating some measure of mineral availability, as well as of concentration, into selection programs designed to improve the mineral nutrition of ruminants.

FERTILIZATION EFFECTS ON MAGNESIUM CONCENTRATION AND AVAILABILITY

The effects of the main fertilizer elements on the uptake and utilization of magnesium by plants and animals are well documented. Fertilizer nitrogen alone tends to increase the concentration of magnesium in herbage, where soil magnesium is not limiting. Potassium fertilization increases herbage potassium levels, but decreases the concentration of magnesium. Where nitrogen and potassium are used together, the incidence of grass tetany has been observed to increase, although the reasons for this response are not clear. Some possible causes might be: (a) an effect of both nitrogen and potassium in depressing availability of magnesium to the grazing animals; Fontenot (1973) considers that potassium is more important in this respect; (b) an effect of nitrogen fertilization in depressing the soluble carbohydrate of the grass, causing a protein-energy imbalance in the grazing animal, and (c) an effect of nitrogen in increasing the level of higher fatty acids in herbage, with possible formation of insoluble calcium and magnesium soaps in the gut of the animal.

While soil treatment with dolomitic limestone is a frequently recommended practice for the prevention of grass tetany in eastern mountain areas, there is limited experimental evidence to support the effectiveness of this measure. Amos *et al.* (1975) noted a higher concentration of magnesium in immature orchardgrass treated with dolomite than with calcite, and some response in blood magnesium of ewes maintained on the dolomite-treated pastures. Pennsylvania trials with quicker acting magnesium fertilizers such as kieserite (Gross, 1973) indicated that significant increases in magnesium concentration were obtained in both grass and legume species in response to relatively low fertilization rates (56 and 112 kg Mg/ha), although uptake was related to soil type. Response will also vary with growth stage. Increase in magnesium concentration resulting from fertilization with 112 kg Mg/ha in the sulfate form was greatest early in spring and least at the hay stage and in regrowth cuttings (Reid, unpublished data).

In recent trials (Gross and Jung, unpublished data) with different species under greenhouse conditions, a high magnesium fertilization rate (672 kg Mg/ha) significantly and differentially influenced the magnesium concentration of both grasses and legumes. Smooth bromegrass (*Bromus inermis* Leyss.), tall fescue (*Festuca arundinacea* Schreb.), birdsfoot trefoil, Saranac alfalfa, and ladino clover (*Trifolium repens* L.) responded best to magnesium fertilizer under cool spring conditions, while Timfor timothy and crownvetch (*Coronilla varia* L.) were most responsive at cool autumn temperatures. Grass species which responded well to fertilization at cool temperatures tended to show little change in magnesium concentration under higher temperatures. Fig. 4 provides a summary of the average absolute increase of magnesium concentration in the topgrowth of grasses and legumes under all temperature regimes in this study. Nordstern orchardgrass was the most responsive of the grasses, while the crownvetch cultivars and birdsfoot trefoil showed a greater overall ability to use fertilizer magnesium than white clover and alfalfa.

The authors suggest that use of such high levels of magnesium fertilizer might be economically justified by application to limited areas of pasture prior to grazing at critical tetany periods, on much the same principle as foliar application methods. Again, the effectiveness of such an approach will depend upon the ability of the animal to utilize efficiently the increased amounts of magnesium incorporated in the plant. To determine the effect of magnesium fertilization of forages on utilization by the animal, mineral balance trials with lambs were run on 19 hays harvested on different soil types in West Virginia and Pennsylvania (Reid *et al.*, 1975). The hays included grasses and legumes of different species,

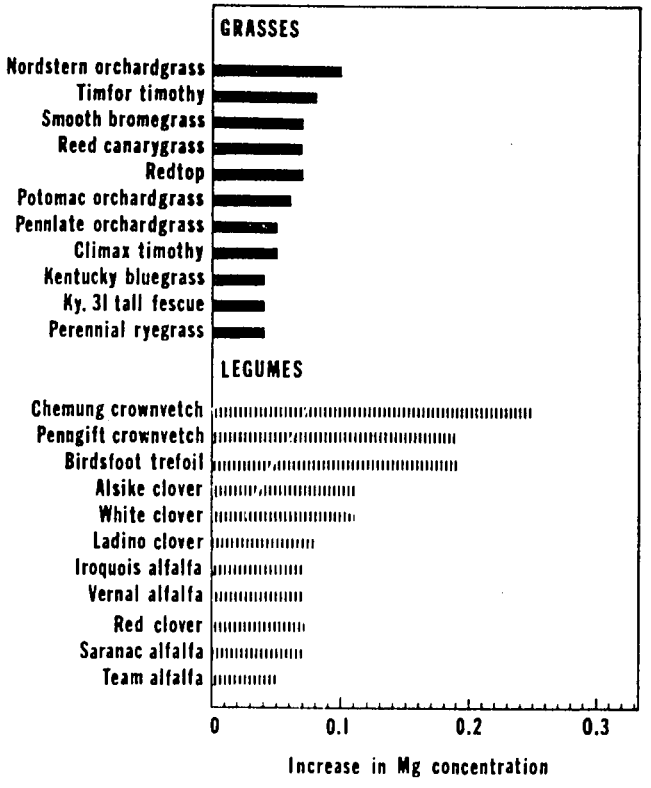

Figure 4. Mean absolute increase in magnesium concentration of grasses and legumes at cool, intermediate, and warm temperatures in response to magnesium fertilization under greenhouse conditions. Magnesium was applied at the rate of 672 kg Mg/ha in the form of $MgSO_4.7H_2O$. Gross and Jung (unpub. data).

harvested at different growth stages, and fertilized with or without 112 kg Mg/ha, magnesium being in the form of kieserite, 94% $MgSO_4.H_2O$. Magnesium fertilization increased the concentration of magnesium in the forage (0.17 vs. 0.20% for non-fertilized vs. fertilized forage across all species), had a variable effect on apparent absorption values, but significantly improved magnesium retention (0.17 vs. 0.28 g. Mg/day) by lambs. Apparent absorption and retention of magnesium in response to fertilization were significantly higher on legume hays than on the grasses.

PRACTICAL METHODS FOR CONTROL OF GRASS TETANY

Two situations need to be considered in developing prevention methods. In the "acute" spring tetany syndrome, serum magnesium levels in cows turned on to spring herbage decrease rapidly and the susceptible animal may become tetanic within three or four days of the onset of grazing. In these conditions, supplying magnesium in available form directly to the animal, either by supplementation or

by foliar application, appears to be more effective than increasing the level of plant magnesium by fertilization. Fig. 5 shows changes in serum magnesium concentrations of beef cows grazing orchardgrass in early spring under three treatments: (a) "high risk" pastures fertilized with N and K; (b) the same pasture treated with N, K, and 168 kg Mg/ha, as kieserite; (c) high risk pastures, with a dietary supplement of compressed molasses-MgO blocks (a commercial preparation containing 14–15% magnesium and 19–32% salt). Results indicate that the provision of blocks on pasture was more effective in raising blood magnesium levels quickly after the initial drop than the magnesium fertilization treatment. The average consumption of magnesium from the blocks over a three-week period on pasture was in the range 18–25 g per cow per day. Alternatively, workers in Virginia (Fontenot, 1973) have reported satisfactory consumption of magnesium by grazing cows from mixtures containing 1 part trace mineralized salt, 1 part magnesium oxide and 1 part of a palatable feed such as dry molasses, cottonseed meal, steamed bonemeal, corn distillers dried grain, alfalfa meal, or ground corn.

Foliar application of low levels of magnesium oxide on spring herbage provides effective protection, but this approach is seldom followed under hill farming conditions, probably because of limitations of equipment and terrain. Similarly, standard recommendations on the timing and level of application of fertilizer N and K to prevent spring tetany on hill pastures tend to be of academic rather than practical interest.

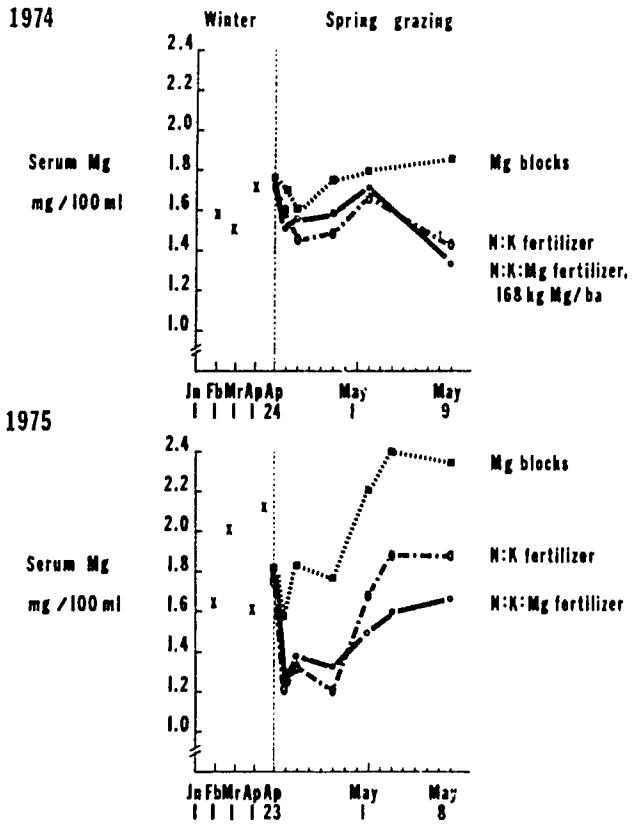

Figure 5. Changes in blood magnesium of beef cows turned on to spring pasture (orchardgrass) under three treatments. Values are means for groups of 12 cows.

To meet the more chronic situation of winter tetany, it should be recognized that most beef cow herds on hill farms are maintained during the winter months primarily on mature grass hay or fall-saved pasture and seldom receive either silage or grain supplements. O'Kelley and Fontenot (1969, 1973) estimated that, for lactating beef cows, levels of approximately 21, 22, and 18 g dietary magnesium were required to maintain serum magnesium levels of 2.0 mg/100 ml during early, mid, and late lactation, respectively. Of this requirement, approximately half will be supplied by the forage. A further 10 g magnesium would therefore need to be provided from supplementary sources. In trials in Virginia, Fontenot (1976) concluded that this amount of magnesium could be obtained from a simple mineral mixture containing 1 part trace mineralized salt and 1 part magnesium oxide. In Ohio studies (Bishop *et al.*, 1971) consumption of such a mixture was found to be extremely variable, and in West Virginia, average consumption of magnesium by beef cows given a free choice mixture of 40% salt, 40% dicalcium phosphate, and 20% magnesium oxide ranged from 1.3–4.2 g/head/day (Reid, unpublished data). This compared to an intake level of 5.0–10.0 g magnesium from a similar mixture containing 20% dried molasses, or 4.1–8.8 g magnesium from commercial molasses-MgO blocks (15% Mg).

The use of such blocks under field conditions has been tested extensively in the Allegheny Highland Project in West Virginia, and Woodson (1974) reported good results in tetany prevention from their use on hill farms. Precautions in feeding include: (a) provision of one block per five cows; (b) removal of other salt sources; (c) positioning of blocks where cows have ready access to them; (d) prevention of block soiling and wastage.

While use of more palatable mineral mixes undoubtedly increases the average level of consumption of magnesium by wintering cows significantly, it does not completely solve the problem of variability of intake by individual animals. Behavioral studies (Reid, unpublished data) over two winter periods indicate that, while most cows in a herd use mineral supplement boxes regularly, some animals do so very infrequently. An alternative approach may therefore be to provide the magnesium in the water supply. This technique has been used successfully in New Zealand (Young, 1973, 1975) and consists simply in dissolving or metering a soluble magnesium salt such as magnesium sulfate

(Epsom salts) daily into the herd drinking tank. Results of such a trial in West Virginia are given in Fig. 6. Addition of Epsom salts to a stock tank to provide an average daily intake of 14 g magnesium per head effectively increased the serum magnesium levels of beef cows during the winter period and had no deleterious effect on water consumption nor any apparent effect on scouring or health of the animals. The cost of the treatment was comparable to that of use of magnesium blocks, and the treatment was effective in raising the blood magnesium of all animals in the experimental group.

Other possibilities for hill land use might include the use of magnesium boluses and the inclusion of magnesium salts in liquid supplements and licks; neither of these techniques has proved particularly successful under field conditions, the main problem being a failure to supply adequate amounts of magnesium to meet the requirements of the lactating cow.

ACKNOWLEDGMENT

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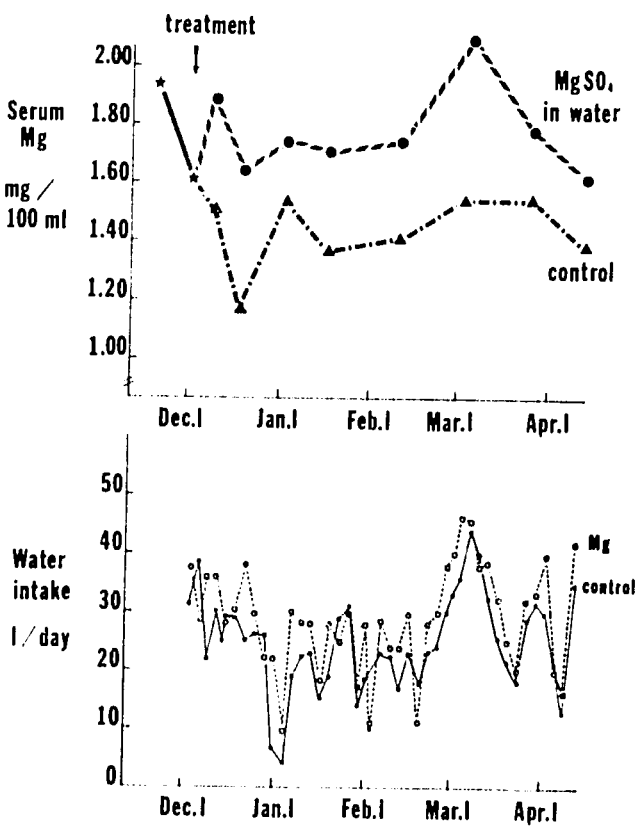

Figure 6. Serum magnesium concentrations and water intake of beef cows maintained during the winter on grass hay, salt, and either water or water containing magnesium sulfate.

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DISCUSSION

F. P. Horn (Oklahoma, USA). What is your feeling on the relative importance of calcium in the grass tetany problem? As you know, in animals on wheat pastures in the South we find low blood Ca levels but not often low Mg.

Reid. Hypomagnesemic tetany often involves a deficiency of Ca and may, in fact, represent a type of spectrum between a deficiency of the two elements. In cases of both spring and winter tetany in West Virginia in which we have followed blood mineral changes we have, however, found that the primary change is in Mg and that the blood concentration of Ca stays within a normal range.

R. E. Blaser (Virginia, USA). I would expect that you might get differences in Ca retention with different plants. Possibly the cutin on the leaves or chlorophyllins might inhibit contact. You might resolve this by grinding materials finely.

Reid. So far we have worked with fresh plant material and haven't looked at possible effects of processing on mineral availability. In addition to Mg, there are significant differences in the availability of elements like Ca and P between plant species, and it seems possible that these differences may affect other parameters of animal performance such as digestibility, intake, and growth rate. They may, for example, be involved in the poor performance of cattle and sheep on tall fescue. Other work—as in Wales—has shown that species and cultivars of grasses may differ in micro-element availability and that this can affect the performance of lambs. We don't know what factors in plants may alter mineral availability.

R. W. Brougham (New Zealand). Have you looked at variation in water intake by cows in your winter situation? Experience in New Zealand with bloat preventives given in water indicates high animal variation in consumption and this might be a problem.

Reid. We have only measured water consumption in these trials on a group basis, but I suspect that you may be right. Behavioral studies with cows given choices of mineral supplements have shown very marked variation among animals in the frequency with which they use mineral boxes. Blood composition does, however, show that all animals on the Epsom salt treatment in the water had higher Mg concentrations. Cost of this treatment, incidentally, is much the same as for Mg blocks—3 to 4 cents per head per day.

W. Mosher (Oregon, USA). Is there a relationship between Mg and K in the animal diet in causing tetany?

Reid. Yes, I'm sure there is. We are on high K soils here and a great deal of work has indicated that K interferes with the uptake of Mg. The Dutch workers consider that the N × K interaction may be particularly influential in causing tetany.

112.
Dynamism and Conflicts in the Multiple Use of Hill Lands

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Multiple use of land is an attractive concept. The words seem to convey the idea that each unit of area is serving "double-duty," as though society were receiving something for nothing. Throughout the world politicians have accepted the doctrine readily in recent years, and under their tutelage, and that of journalists, the general public in many countries has come to believe that this is a management principle on which the land and water resources of the world should be run. Multiple use, at least of forest land, has been given the weight of the law in the United States and it appears prominently in the statements of resource policy of several nations.

The object in this paper is to consider the application of multiple use to the management of hill land in general, drawing some evidence and examples from the situation in the recent past and present in Scotland.

Multiple use of land means using a particular area to produce more than one good or service concurrently. Simple subdivision of a large area into discrete units, each used exclusively to produce one good or service, does not constitute multiple use, nor, in the view of most people, does the alternation of uses over a time period of more than one or two years, although there is some disagreement on the point.

For the logical development of the subject it is probably unfortunate that the term *multiple use* has come to cover both the deliberate decision to produce more than one good or service from a land unit and the situation where other goods and services happen to occur uninvited, in addition to the good that management is trying to produce. The latter condition may be regarded as casual multiple use and is extremely common in extensive grazing systems (range management) and in forestry. On Scottish hill farms where sheep and hill cattle are the principal products, red grouse (*Lagopus lagopus scoticus*), red deer (*Cervus elaphus*), feral goats, and mountain hares (*Lepus timidus*) share the grazings and provide subsidiary products, with public access tolerated throughout the area. The farmer may not try to produce any of these subsidiaries and may find the disturbance of his stock by public access obviously damaging at some times of the year; nevertheless he may accept them all, if only because he cannot afford to rid his farm of them. The subsidiaries may cost less now in domestic stock production foregone than would their destruction or exclusion. The decision to change the margin at which the farmer would take action against them depends on prices and costs; an increase in the price of a major product would cause the farmer to review the cost of the subsidiaries, in principal production foregone, and hence the desirability of eliminating them.

Similar casual multiple use occurs in forestry; in some instances the forester may accept the inevitable joint production (say, the presence of roe deer (*Capreolus capreolus*) which damage young plantations severely by browsing), and, making a virtue of necessity, may call the result multiple use.

There are, in contrast, many instances where the multiple use is the result of a positive management decision, as in the mixed trees and grazing system in New Zealand (e.g., Knowles *et al.*, 1973). Different though the casual and planned multiple use may appear to be, each fits well into an optimization strategy, that is to say into a logical management regime for producing the desired goods at least cost, or for maximizing the yield or the profit margin of the desired system.

This is precisely how multiple use was approached by Gregory (1955) in what is still the key paper on the economics of the subject. Gregory's model, given suitable data, would indicate for a particular management situation, whether multiple use was economically justified and the amounts of the various goods considered which would yield an optimal result. As with any optimization procedure, the model requires the operator to define the criterion upon which the alternatives will be judged, that is, the statement of an objective. In contrast, the adoption of multiple use as a popular panacea has allowed it to emerge, however illogically, as an end in itself, as if the yielding of many compatible products was particularly desirable and capable of maximization.

The relationships of product to product in respect of their compatibility in any situation range from joint production to direct competition. These conditions are not discrete, but form a catena of declining compatability which corresponds inversely with the intensity of management. Whether hill or lowland, extensively managed land tends to produce more than one product, and capacity for multiple use (or

tolerance of it) diminishes as the intensity of use increases. The fact that the farmer may receive an income from the subsidiary products of casual multiple use may confuse the issue superficially. Nevertheless the association of multiple use and extensive management arises mainly because the manager finds he has more to gain by using his scarce resources of supervision and capital on the production of his main product X than by diverting them to the elimination of the secondary products Y and Z. Later, when he has intensified the system by devoting his attention, labor, and capital to the most urgent improvements in system X, he finds that the next increments of input factors would be more effective in eliminating system Y or Z, a stage which is commonly identified as the margin of compatability and competition in the product-product relations.

Let it be supposed that the proprietor of hill range in Scotland decides to increase cattle grazing by pasture seeding, paddock fencing, the provision of water, etc. The increased financial commitment makes the farmer intolerant of red deer and hares which clearly reduce his more valuable cattle production and may yield him little or nothing, for instance if the deer use his farm in the closed season for shooting. Even public access becomes unacceptable as people break the fences and disturb the stock. The farmer will have to take account of what the reseeding may cost him in the abandonment of the revenue-earning grouse shooting because of the elimination of the birds' required heath habitat and diet. As the intensity of management and capital commitment increases in any system, so casual multiple use declines. The agricultural extreme of the catena from range management is in indoor farming, say in deep litter poultry, where not even a mouse is tolerated, far less a red deer. These creatures, extraneous to the cultivated system, would not yield "something for nothing," but would clearly divert inputs from the desired product, and their cost would be the reduction in the harvest sales.

The production functions associated with hill land are very frequently less advantageous to man than those on lowland, because the soils are thinner, less fertile or more fiercely drained, or the climate is harsher than in the lowlands; or it may be that the most productive machines cannot operate efficiently on the steeper gradients, or that the best land use opportunities require careful terracing of hill land before one may even begin to grow the crops which could be raised on level ground. The hill land production functions being generally poorer than those on the lowland, capital investment per unit area tends to be less attractive and is smaller than in the lowlands (see Table 1), so land use in the hills is generally far more extensive than on the low ground. This itself accounts for a high proportion

TABLE 1. Farm tenant's capital by farm type, southeast Scotland, 1974–75

Farm Type[a]	Mean Size of Farm (ha)	Tenant's Capital[b] (£ per ha)
Hill	1 130	23
Upland	418	81
Rearing with arable cropping:	192	160
Low intensity[c]	144	179
Medium/high[d]	171	279

Source: East of Scotland College of Agriculture, 1976.
[a]Farm type by standard definition of Department of Agriculture and Fisheries for Scotland.
[b]Average of opening and closing valuations of farm accounts.
[c]Cereal cropping.
[d]Cereals and other cash crops.

of the supposed multiple product management and multiple use of hill lands; since they are not intensively managed, casual multiple use is normal.

There are clear exceptions to such a generalization, where the use of hill land is intensive, as in the Chianti Hills in Italy where the peculiar soil and climatic conditions favor wine growing. In the Chianti, the intensification for viticulture produces a landscape which is less appealing to the tourist than the traditional Tuscan mixture of olives, wheat, vines, vegetables, etc; under the influence of price for good Chianti wine, land use moves to a single product system which is much more lucrative to the proprietor. If society were to insist, for aesthetic reasons, on continued multiple use and diversified production (because visitors enjoyed seeing white oxen and a mosaic of crops in each field), the farmer would be denied the opportunity to increase his income from the management of his property and a problem posed as to how he could be recompensed for the denial of better revenue or induced not to proceed with the change.

Several points emerge from such evidence of change. First, there is the reminder that land use is dynamic, under the influence of changes of demand, product prices, and costs; Gregory's model can test the sensitivity of the system to price and cost changes. The second point is that where land is scarce (either any land or land of a particular quality), suitable hill land does attract capital investment and improvement which makes intensive management necessary and multiple use unlikely; it is the existence of more attractive investment opportunities elsewhere that keeps most hill land undeveloped. Third, an artificial retention of multiple use always represents a lost opportunity for the proprietor and a potential loss of revenue; admittedly, it may be more than offset by a non-market benefit

which accrues to another person or group, but someone must sustain the revenue loss. It may fall on the proprietor or it may be shared by society. Fourth, the increase in the intensity of land use and the accompanying reduction of multiple use presents fewest problems when the proprietorship and the enjoyment of the multiple products are in a single person or few people, and they present most problems when the land is owned by one person and the multiple use services are enjoyed by society at large.

The current situation in Scotland is an interesting one in respect of multiple use of hill land. Of the total area of the country (7.63 million ha) more than 60% (about 4.68 million ha) is hill land, used as rough grazing for domestic stock and wild animals, approximating the open range in the American sense. Some is bare mountain and quite unproductive, for although the peaks are not particularly high (up to 1400 m) the country is in a high latitude and the vegetation is similar to the middle-alpine zone (McVean and Ratcliffe, 1962). Most of the hill land is in few proprietorships (between 300 and 400 occupy approximately 3 million ha), and the hill area is very sparsely inhabited, much of it at less than 1 person per 100 ha, making it one of the most empty parts of Europe. McVean and Lockie (1969) provide an excellent modern account of land use in upland Scotland.

The Scottish hill land is not very productive (DAFS, 1976): each 100 ha supports, on average, about 50 sheep and 5 hill cattle. The domestic stock is managed extensively, with very few fences or improved paddocks, and as a result there is casual multiple use. The natural woodland has long been destroyed over most of the area, and the vegetation is dominated by heather (*Calluna vulgaris*). On these open hills there are many wild red deer (the national herd numbers about 300 000) and, in the drier climate of the eastern Highlands, the game bird red grouse is common. Both red deer and grouse are important animals for sport shooting. The public has effective access to the whole of the unenclosed land, although the proprietor may ask a visitor to leave if he is doing damage (e.g., disturbing the stock), and in theory could even call the police to make an eviction. (In practice it is not easy to prove the damage and it is often extremely difficult to find a policeman in the middle of the Highlands.)

The pattern of use of the hill land in Scotland has been changing quite markedly over the last 20 years, although it is probable that all the elements of tension and factors for change were present a hundred years ago, albeit with differences of emphasis. The hill farming problem has been basically an economic one, with labor costs (which may be 50% of total costs) increasing more rapidly than product prices. The decline in demand for mutton (as opposed to lamb meat) and especially for wether mutton, has resulted in the steady reduction of wether flocks which, broadly, occupied the higher and more remote sheep areas. There has been a resulting concentration on ewe flocks to produce lambs for lowland cross-breeding and fattening, and a marked increase in cattle numbers, by about 80% in ten years (DAFS, 1975), from 261 000 in 1965 to 478 000 in 1975 (although this number has probably fallen somewhat in 1976).

The virtual withdrawal of sheep from the more remote hill areas has allowed sharp increases both in the area grazed by red deer and in their numbers, with the national herd increasing by perhaps 50% in 10 years to about 300 000 head (RDC, 1976).

Concurrently with these changes a successful program of afforestation has been followed on the lower hill slopes, up to about 500 m. In some instances, afforestation has been done by the existing landowners, but more often has followed land purchase by the Forestry Commission (the national forest authority and state forestry enterprise) or by a private forestry company. Since 1960 the Forestry Commission (F.C.) in the Scottish uplands has planted at the rate of about 15 000 ha per annum (rising from about 10 000 to 20 000 ha per annum: F.C. Annual Reports) and the private sector has achieved between 6 000 and 17 000 ha per annum. The immediate importance of the afforestation for other uses of hill land lies mainly in three facts: that the new forest is not in the same proprietorship as the neighboring range land; that in an effort to be financially successful the new forest is composed principally of Sitka spruce (*Picea sitchensis*) and Lodgepole pine (*Pinus contorta*) which are productive but liable to severe damage by deer; and that it is fenced against domestic stock and deer.

Large areas of the Scottish Highlands are used almost exclusively as sporting estates for grouse and deer. Politically, the existence of these sporting estates has become something of an issue (Select Committee on Scottish Affairs, 1972), in spite of the fact that the ownership of them results in a considerable private subsidy from the city to the country. Large as these land holdings are, they yield a very modest revenue to set against the expense of their maintenance, and over a large area sport shooting is the most productive land use available and provides more employment than supposed alternatives.

Forestry and agriculture were explicitly excluded from the terms of the Town and Country Planning (Scotland) Acts, so that there is no positive direction of rural planning. It is notable that many authorities each have responsibility for a narrow sector of rural affairs: The Nature Conservancy Council, the Forestry Commission, Countryside Commission for Scotland, Red Deer Commission, Hill Farming Research

Organization, Institute of Terrestrial Ecology, Department of Agriculture and Fisheries for Scotland, etc. There is no single body responsible for rural planning, monitoring, or management.

As the economics of holding hill land have become more adverse, with rising labor charges in particular, pressure has arisen in almost every system of production to achieve a better financial result. The tendency has been the expected one: the concentration of investment in the places where it would be most productive, in reseeding and draining the better land for improved grazing systems and afforesting the lower hill slopes. The withdrawal of domestic stock from the higher hills (either completely or for a longer period each year) has been accompanied by an increase in deer numbers (RDC, 1976; Mutch *et al.*, 1976). Deer present a sharp point of conflict where they migrate to low ground, as they do normally each winter, whether to forest or improved farm land.

Concurrently with these changes, there has been a large increase in the number of people using the Scottish hills for recreation, from within Scotland, from England, and from abroad.

All these elements combine to make for change in multiple use and the creation of problems for those concerned with resource allocation.

In broad terms there is little conflict between the traditional extensive hill sheep system and grouse shooting. Both the sheep and the red grouse take the young shoots of heather as food, and it is possible so to manage the heather by rotational burning in small patches or narrow strips that sheep and bird populations benefit. At this low level of factor inputs (basically vegetation management by controlled burning) the two systems have a wide range of compatability for multiple use. The grouse, however, is heavily dependent on the heather being burned in small patches (Jenkins *et al.*, 1963, 1967), which is labor intensive, whereas the sheep system can be sustained on less closely controlled burning. As the economics of the system become more difficult and labor in remote places scarcer for controlled burning, the two systems are less compatible; expensive small-mosaic burns must be justified by grouse revenue if they are to be achieved, since the sheep enterprise does not expect to carry the extra burden. Where sheep and grouse are in the hands of one proprietor this conflict may be ignored or obscured for some time, but where the grazing and the shooting are in different hands, it is more obvious.

In a 1974 survey of game shooting and land use in the Scottish Highlands, a sample of 94 estates totalling more than a half million ha reported 82 000 grouse shot in the season, at a mean rate of 15 birds per 100 ha. The highest mean for a class of estates (36 properties with mixed grouse, red deer, and domestic animals) was 37 birds shot per 100 ha. The survey data (to be published shortly) show that the grouse bag is poor on areas from which domestic stock has been withdrawn (2 grouse shot per 100 ha).

The compatability of grouse shooting and sheep grazing has been extended and supported by the constraints which some landlords who retain the sport shooting have placed in the leases of their tenent sheep farmers in the past, whereby the number of sheep which may graze the rented area has been restricted. As the economics of sheep farming became more difficult after 1950, especially with the increase of shepherds' wages, there was a strong incentive to increase the number of ewes per holding. In practice some leases which specify maximum numbers of sheep to be grazed are not enforced in that respect, but the condition was a tacit admission of the potential competition between the systems. Certainly a move in sheep husbandry towards pasture reseeding seems inevitably to reduce the compatability of sheep and grouse. The complete replacement of heather by grass must inevitably reduce the capacity for grouse breeding because of their strong food preference for heather. Even in a partial reseeding the concentration of husbandry and investment on one part of the farm, using the higher hill as an out-run, makes the care of the heather land less urgent than formerly, so that there is a weaker case from the point of view of sheep production for the labor-intensive patch burning on which grouse remain dependent. In view of the high rents currently available for grouse shooting, amounting to about £150 per gun per day (say, $ 260) for good shoots, there is no likelihood of the grouse system disappearing, but it is probable that there will be continued specialization towards monoculture.

The position in respect of land use by red deer is similar. Red deer make use of approximately 3.1 million ha in Scotland, although perhaps only 1.6 million ha exclusively. An experimental farm has been established at Glensaugh, an upland farm not far from Aberdeen (Blaxter *et al.*, 1974), to study the possibility of intensive husbandry and domestication of deer, but there is no likelihood of the results being applied to the main wild deer area in the high mountains, even if complete success of the farm trial encourages venison farming in the uplands as an alternative to other animal husbandry. The main pressures on the wild deer system arise from rising labor costs and from its increasing isolation as improved grazing and forestry occupy the lower hill land and deny to the deer what was formerly the wintering ground of a much smaller national deer herd. The Red Deer Commission, in evidence to the Select Committee on Scottish Affairs (1972), said that "In terms of revenue, deer themselves are not a viable proposition." Nevertheless, prices have increased recently; stag shooting may

be let at £50 or more per head ($88) and venison now fetches £1.20 per kilogram ($2.10) for the cleaned carcass (larder-weight) (Mutch *et al.*, 1976).

Systems of land use in the hills are under pressure to become more productive, to yield a higher return on invested capital, to give more timber or more animal products in order to meet increased wages or a wider margin for the operator's income, and, in addition, these systems are under pressure from higher demands for non-priced recreation. In Scotland, as elsewhere, this process has involved the commitment of more expenditure on such items as roads, fences, mineral fertilizers and machinery, and on housing, purchased feed, and veterinary care for stock. The scope and general possibilities of such intensification may be seen in an example from West Scotland. At Fassfern, a hill farm of 2000 ha, the former extensive management carried a stock of 500 Blackface ewes, 100 young sheep, and 30 cattle; the lambing percentage was 65%. Since 1970, farm production has been intensified on 360 ha, at a capital investment of about £50,000, allowing the remainder of the property to be put under forestry plantations, at a net investment, with roads, of a further £130,000. The low productivity traditional hill farm has been changed to yield more on only 20% of the area; the sheep stock is still 500 ewes, but now lambing at about 120%, with 120 hill cows. Total labor employment has increased to nearly ten times its former level (Mutch, 1972). The justification of high capital investment, however, forces management to stop the leaks in the system which produces its best paying product, each system becoming unable to carry the subsidiary products of casual multiple use. As at Fassfern, therefore, the sustention of unpriced benefits (such as environmental diversity and nature conservation) in the intensified situation requires planning and deliberate provision in special areas.

In 1971-72 a House of Commons Committee, the Select Committee on Scottish Affairs (1972), considered land use in Scotland, the allocation of land resources, land improvement and multiple use, taking evidence from a very wide range of users or organizations responsible in some way for land use systems or their research. The evidence of the Nature Conservancy concluded that during the last thirty years there had been greatly increased pressure to maximize the potential production of land in the form of a main crop for man and a pronounced move towards monocultural systems; this opinion was not refuted or shaken by other evidence. Nevertheless the Committee found there was complete agreement among witnesses that the move towards monocultures contained much that was undesirable. It was as if multiple use were ceasing just when the pressure on land systems made it especially desirable and valuable that each ha should "do double-duty." My own opinion and evidence to the Committee was that specialized use is an automatic result of the increased pressure, be it increased pressure of recreationists or tourists, or increased pressure of the proprietor, private or state, upon the manager to produce a better financial result. The normal result of increased pressure on a land use system is towards specialization and away from multiple use.

The impending further loss of multiple use was obviously unpalatable to the members of the Committee who even considered the possibility of maintaining the *status quo* by means of compensation payments to proprietors to persuade them to forego the financial advantages of intensification in order to allow the multiple use to persist. The evidence of the National Farmers Union of Scotland was that if strictures were to be put upon their industry or on individual farmers as to how they should farm their land, compensation would be required for those strictures.

My own view is that man's increasing requirements for indigenous production from the land will gradually force the abandonment of extensive production systems which allow multiple use, and the acceptance of closer husbandry of plants and animals. In Scotland at least, I expect this progression to include a reintroduction of animal transhumance which was used successfully as a production system for centuries before the country was forced into the grazing system which has now become familiar to us. An indication that transhumance may prove both financially attractive and sustainable in modern conditions lies in the successful research and demonstration of a limited form of it on the farms of the Hill Farming Research Organization. A fully developed transhumance system might well involve a substantial change in the tenure of hill land, or at least a redrawing of farm boundaries, but it would have the advantage of using more fully for domestic stock the land extending to about 3 million ha now used largely by wild red deer. As a result there would be a strong economic incentive to reduce the population of wild deer, and in this way both forestry and farming would be relieved of the threat of periodic incursions by large herds and of the high cost of fencing against them. Whether transhumance of domestic stock develops on a large scale in Scotland or the trend towards monoculture continues, it seems inevitable that multiple use will diminish, at least in the present casual sense.

What proprietorship of land means is a difficult issue on which, I suggest, standards are neither unchanging over time nor universal. Many private landowners in Scotland have subscribed to some degree of stewardship (as against a right to act completely arbitrarily), and most have shown tolerance of public access to hill land except at times of the year when stock is specially sensitive to

disturbance (as at lambing) or when activities such as deer stalking are actually taking place.

Nevertheless, I suggest that the capacity for accommodating multiple use in Britain, and probably in Europe as a whole, is quite different from that in the United States of America. The United States has about 4 ha of land per inhabitant; Britain has approximately 0.4 ha per person. In any country where there is a relative abundance of land there is a likelihood that a high proportion of land, and especially public land, will be combined with a small amount of capital per unit area and that multiple use will be normal. In this situation literature and even legislation do no more than confirm the normal state of affairs and formally recognize its desirability.

Where land resources are scarce, as in Britain where half the food and 85% of the wood and lumber products consumed are imported, it is difficult to be convincing that productive land resources should be kept artificially underused for production so that multiple use can occur, in spite of the fact that most people prefer the appearance of the multiple use situation to the intensified one.

This is even more clear in the Netherlands where dense human settlement and intensive farming on a small land resource are such that public access as casual multiple use is seldom possible; the Netherlands State Forest Service (1966) has estimated the area of forest and open countryside at less than 340 m^2 per head of the population. The strong demand for public access to forest has caused the forest service to put access or nature conservation before timber production as the prime management objective over most of its area, but since the state owns only about 16% of the total forest area, much of the demand remains to be met on private land. The Dutch government offers the incentives of large cash payments and tax reductions to induce private proprietors to allow casual public access and to promote nature conservation on private land. Private land proprietors may receive an annual payment towards the costs of opening (paths, sanitation, etc.) and costs of conservation, on a reducing scale with increase in the area of the property:

For the first 50 ha
D fl 60 per ha (£13.26 or $23.16 per ha)
For the area 50 to 100 ha
D fl 50 per ha (£11.10 or $19.30 per ha)
For the area 100 to 200 ha
D fl 40 per ha (£8.84 or $15.44 per ha)
For the area 200 to 500 ha
D fl 30 per ha (£6.63 or $11.58 per ha)
For the area over 500 ha
D fl 20 per ha (£4.42 or $7.72 per ha)

(Source: Netherlands Ministry of Cultural Affairs, Recreation and Social Welfare)

Municipalities also qualify for the payments in respect of their forests. These payments are additional to the support given to private landowners in partial remission of property tax and estate duty under the Netherlands' 1928 Natural Scenery Act, generally for allowing the public to walk in the woodlands and accepting state supervision of management for 25 years. Taxes may be reduced to less than half. The agreement is voluntary and proprietors may withdraw their woodlands from the scheme, but if they were to do so within 25 years they would have to refund the taxes remitted (Netherlands State Forest Service, 1966). In addition to the payments to promote the multiple use of private land, very large resources have been allocated to create areas for public recreation. A famous example was the 895 ha recreation area made in 1934 on the edge of Amsterdam, but more recently approximately one-third of the 44,000 ha polder of South Flevoland has been designated recreation forest and nature reserve, with similar areas going to farming and to urban and industrial development; at 1970 values this land cost approximately £1,000 per ha ($1,740 per ha) for reclamation.

In Scotland at present the major pressures which may lead to sub-optimization on hill land are not those concerned directly with public recreation, but arise rather from a concern over the afforestation of treeless land and the latent conflict between large herds of migratory deer on mountains above the tree line and new forests on their present wintering grounds.

One of the strongest objections to specialization in land use (and particularly to monoculture) is that the financial advantage of the new system to the proprietor may be short-lived and achieved only at the cost of long-term deterioration of the basic resources: that the specialization will not be a sustained yield system. This is implied in much of the literature on the subject and even in the U.S. Multiple Use-Sustained Yield Act of 1960.

There have been many clear examples of unwise specialization which warrant the anxiety expressed in the literature, but it should not be taken as the corollary (although it often is) that a multiple use system, per se, insures sustention. The common extensive grazing system of the Scottish Highlands, as has been shown, offers a large amount of multiple use, but there is a strong probability (for instance, see McVean and Lockie, 1969) that over most of the area this is a degrading, non-sustaining system. Similarly in forestry: it seems a rash assumption, and basically illogical to suggest, that multiple use guarantees sustention, or even increases the likelihood of achieving it, in a harvested system. The evidence is rather the reverse: low input management systems offer opportunity for harvesting which can deplete the capital (either deliberately by the opera-

tor, or casually owing to inadequate monitoring), whereas in intensive use the operator who has committed a large capital to the system has a strong incentive to insure that it is maintained unimpaired in its productivity. Horticulture and intensive animal systems offer numerous examples. Where there is a conflict of principles, multiple use is infinitely less important than sustention.

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DISCUSSION

R. F. Barnes (Maryland, USA). You gave as an example of the intensity of population in the United States a figure of 4 hectares per capita and 4/10 for the United Kingdom and indicated to some extent that the differences between pressures as they intensify will determine whether multiple use is a reasonable approach and whether it will be sustained or not. Do you have a feeling whether multiple use will cease to be a viable option in terms of per capita land availability?

Mutch. In that scale between 4 hectares and 0.4, no, I don't have a precise figure to put on it. Indeed, it may be dangerous to look at this in terms of simple averages alone because obviously the eastern part of the United States is heavily populated. One could choose particular countries which are just as heavily populated as Holland. But I think that the existence of investment opportunities or the pattern of investment opportunities on agricultural land and forest land does make a clear distinction between the closely settled areas of the eastern United States and Dutch situation. I think that for a long time it will be convenient and entirely appropriate and natural for the United States to expect multiple use to remain a viable proposition on public lands and on quite a lot of privately owned land. But this is certainly ceasing to be the case even in Scotland, parts of which are extremely sparsely populated. Even there, the pattern of investment opportunity indicates that land which is sparsely populated in itself does offer effective investment opportunities for agriculture and, therefore, it is tending even there to go towards intensive use and towards monoculture. If we want to retain the nature conservation areas and so on, then we have to move towards the situation of providing explicitly for them by turning over areas as nature reserves and so on and the same is becoming true of recreation areas as well. We have not yet reached the situation of Holland.

T. J. Maxwell (Scotland). You stated that you thought intensive management systems would tend to preclude multiple land use. Now, admittedly one has to think of intensivity as a relative term but I would have thought that our own particular opportunities for multiple land use in Scotland between, for example, agriculture and forestry, particularly where it would tend to remove land from agriculture, that could come about without necessarily reducing the opportunities for viable production in agriculture. This would occur if, in fact, agriculture were to intensify its level of production on that kind of land. I was wondering if you'd care to comment on that.

Mutch. This is entirely so. The way in which land use is tending to go between forestry and hill farming is towards the segregation of uses and this is most helpful. We have existed for a very long period, two or three centuries, on rather slack management of our uplands and there is a fair resistance to change, but what can happen when afforestation is well done is that land which is not immediately required for intensive agricultural use can go into forestry, and indeed the transfer, the sale of some of that land,

out of slack hill farming may in fact finance the agricultural improvement on the better land for new farming systems. This is certainly happening. This is not multiple use; this is in fact a reallocation of resources which are in casual multiple use into two more intensive systems and if it's well done then in fact the sale of land finances the intensification. There is a big opportunity for improvement both for the improvement of agricultural systems and for a very considerable afforestation program leading to substantial increases of productivity from the hill areas.

E. deVries (Pennsylvania, USA). I want to reaffirm what you said about the motivations and the situation in the Netherlands where the average per inhabitant is 0.2 ha rather than 0.4 in Great Britain. As you say, the intensification and the choice of one system does not mean monoculture. That very often is the case for the choice, as we heard in this symposium from many people, between the diversified pattern of agriculture and monoculture because even in the Netherlands there is an attempt for one proprietor to have more than one crop, woodland and grassland, cropland and vegetable, on even one little—a couple of hectares—enterprise. I would suggest that also applies to what the chairman just said about the United States. Transportation distances and transportation costs are very important. Now for the public going into nature, distance becomes less important, but because of transportation costs for products, distance is more important and there is also something where planners and land use people and governments looking at zoning and that kind of thing, may have to consider the greater mobility of people and the relatively lesser mobility of products.

Mutch. I do accept what you say. I think that the big lesson that the Netherlands has to offer is along the lines that you mentioned and also the fact that society as a whole has come to the conclusion that it must pay in order to insure multiple use of what was hitherto privately owned and exclusively used forest land. I think this is a lesson which many countries will have to take on board.

113.
Integration of Horticultural Crops with Cattle and Tobacco Enterprises in the Appalachian Area of Western North Carolina

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From a high peak, the wrinkled brow of the world's oldest mountain stretches out in a jumbled heap giving rise to streams that cascade across narrow valleys depositing the soil from unnumbered years of mountain erosion, leaving small areas of cultivatable land. On their journey toward the sea, they pass by 12 880 farms averaging 30 ha per farm, with 4 ha being classed as cropland and 7 ha pasture.[1] Size is not the only limiting factor.

The land is steep, up to 70% slope—too steep, and the soil is too shallow for much farming. Elevation ranges from 365 to 2012 m and seasons at the higher elevations are too short for crops that are successful in lower mountain areas. Thus, the necessity to find suitable alternatives—not only for small farms, but for varying climatic conditions.

[1] *1969 Census of Agriculture*

During the past 40 years, the number of farms has decreased from approximately 32 000 to 13 000 —brought about by the need to increase income from off-farm employment. During the 30's and 40's, mountain people got by the best they could—picking up work here and there, as mechanics or carpenters, growing a few beef cattle, beans, burley tobacco (averaging 0.24 ha per farm), cutting pulpwood, or even gathering roots and herbs. During the 50's and 60's, the area began to feel the impact of industry, and many of the younger people left the farms to find a better way of life—not because they necessarily wanted to, but because of the need to earn a living. This resulted in out-migration from the area and certainly from the farm. The 1969 census indicated a population of 400 000 ranging from a low of 5 180 in the smallest county compared to 145 000 in the largest. These people, along with an influx of tourists,

people building retirement homes, etc, compete for limited land and financial resources. The census figures also indicate that farm operators average 54 years of age with 1/4 under 45, 1/4 from 45–55, 1/4 from 55–65, and 1/4 over 65. Sixty-five percent are part-time farmers, with 37% being under 65 years of age and working off the farm 100 days or more per year. Twenty-one percent are classed as part-time retirement farmers (over 65 years of age).

During the past 40 years, the role of the Agricultural Extension Service, North Carolina State University, in cooperation with the Tennessee Valley Authority, has been designed to assist small farmers in solving problems relating to agricultural production, farm management, marketing, and the acquisition of farm inputs, including capital. The programs have been modified and updated. Our first effort was in establishing tests and demonstrations aimed at reducing soil erosion, establishment of land cover, and the introduction of proper fertilization practices, in support of the tobacco and cattle economy. Current efforts are designed to introduce new enterprises and the subsequent introduction of new technology, upgrading levels of management, and improvement of efficiency to provide a more comfortable level of living on the farm.

The first 20 years of our effort was, in the main, directed toward erosion control and pasture improvement necessary to keep more cattle. Decreasing beef prices in the early-to-mid-50's and increasing standards of living, caused many mountain farmers to find off-farm or part-time employment. At the same time, these, plus other factors, caused the North Carolina Agricultural Extension Service to reassess its educational efforts. In 1956, we involved a group of leaders (Advisory Boards) in each county in identifying problems, defining needs, setting goals, and establishing direction for future program efforts. A paramount identified need was that of "more income." Of the more promising possibilities, it appeared that intensive horticultural enterprises could provide a high return to limited areas of cropland, even though labor inputs were high, and knowledge relative to production was limited. In establishing direction, farm leaders and Extension agents sought to work on those that could best be integrated into the already existing enterprises of cattle and tobacco—both from the standpoint of labor supply and labor conflict as well as the limited cropland areas and small tobacco allotments, which at that time were non-transferable.

Several new enterprises were introduced and expanded as a result of this effort to increase farm income.

Apples, as an enterprise, had been established, but accepted only by a few producers, even in counties where soil and climatic conditions were most favorable. In the mid-50's, income from apples was $2,987,750.[2] In 1975, apples accounted for $15.2 million, down from $23 million in 1974. What caused this increase? First, it was necessary to get potential producers interested: this was accomplished through developing long-range budgets to indicate the profitability, by setting up tours, meetings, and including apple production as a complementary enterprise to cattle production. Demonstrations of varieties, fertilization, pruning, thinning, desease, and insect control were established as methods of insuring that new producers would be successful. The effect was the addition of many producers, mostly young, many who had finished college, who provided a sound base to an ever-expanding enterprise. Presently there are 33 marketing and/or storage facilities and one new processing plant serving the industry: all but four are privately owned. As mentioned earlier, the 1975 income of $15.2 million was short of the 5-year goal of $18.9 million, but during a good production year, 1974, we exceeded the goal by $4 million.

Strawberries seemed to offer an excellent alternative as a crop that could provide high returns to limited land and investment as well as utilize available labor. Concentration on this crop began in the early 60's as we embarked on a five-year long-range planning effort—"1.6 in 66." Although strawberries were not accepted as well as anticipated, they did provide many families with additional income. In 1975, income was $1.2 million. During the latter 1960's we were involved in another long-range five-year plan which was termed "Target 2." Objectives in both planning periods were aimed at increasing income. (The first from $1.2 to $1.6 million and the second from $1.6 to $2 million.) Goals for each enterprise relevant to a given county and district were established. In establishing goals for "Impact '76" (our current long-range plan), we projected strawberries to reach $1.5 million by 1976, but based on observations of 1975–76, we expect to level off in the neighborhood of $1 million.

During the period of the 40's to the early 60's, the mountain area was noted for the production of beans and potatoes, with some cabbage being produced in higher mountain elevations. Initially, many new horticultural crops can be produced in small areas as long as the competition has to also produce by hand labor; however, when technology advances to the point that mechanization is developed, these crops move to areas of least production costs (large holdings) as experienced with beans and potatoes.

To replace this income, attention was focused on other enterprises that would give high returns to land and labor. One of the more fascinating is the production of Fraser fir (*Abies fraseri*) for Christmas

[2]All income figures are taken from official county Extension estimates of agricultural income and are reported in terms of current dollars.

trees. Fraser is native only to a few selected sections of the United States—particularly in the higher elevations of western North Carolina. Getting farmers to accept a new enterprise is an involved process—ranging from result and method demonstrations to just plain salesmanship. Most of all, it requires that the enterprise be a profitable one, and that it can be produced with minimal tie-up of resources. The Extension agent working with farmers must be a dedicated promoter and exhibit a high degree of technical knowledge. As is usually the case of newer enterprises, very little technical production information is known; therefore, it is necessary that the Extension agent, the Extension specialist, and the researcher establish research plots on cooperating farms to look at such things as types and rates of fertility, pruning, tree quality, etc. as they affect both rate of growth and quality of tree. By 1975, income had reached $3.1 million—$1 million above that projected for 1976. This year it is expected to exceed that since all trees have been sold for several months. This crop currently gives a gross return of $4,706 to $5,683 ha/yr, depending on spacing. Farmers also are presently producing sheared white pine (*Pinus strobus*).

One of the more interesting enterprises—both as a crop and from the standpoint of Extension efforts to help increase farm income—has been trellised tomato production.

In 1957, one grower produced 1 ha. The resultant story, almost a parallel to the "Cinderella Story," has been one that more closely exhibits the impact of a new enterprise on the economy of an area than any that I know of. In 1958, 7 ha, with 30 growers in 2 counties, were involved. As a result of records of returns compiled from the 1958 crop and subsequent efforts of agents to present the results to potential producers, over 121 ha were grown in 1960. Ten years later, 522 ha were being grown by 1846 producers. Gross income was $4.9 million. Let us look at the cumulative effects of this crop on the economy for the first ten years.

During the first ten years $32 million of tomatoes were sold. To handle the crop, 17 packing plants were built with a cumulative investment of $1,073,500. Employment within the plants in grading, packing, and shipping increased payrolls by $2.4 million.

Labor to handle the crop amounted to a cumulative total of 9.4 million man hours, giving part-time employment to many (aged, women and children) who could not have been gainfully employed elsewhere. To look at the effect of the crop on sales of inputs, let us examine what was involved in production by following the crop on a seasonal basis.

EXPENDITURES

a. To fumigate plant beds required $234,000 for methyl bromide, $71,000 for plastic, plant bed cover, and seed.

b. Fertilizer and lime costs were estimated at $940,000.

c. Plant setters, stakes for trellising, and stake drivers would have cost $267,000.

d. A most astounding expenditure was in the form of wire and twine for trellising, amounting to $99,542 for wire, and $334,830 for twine. A lot of string by any method of measurement; however, necessary to support a crop whose highest yield has been in excess of 209 MT/ha.

e. Growers spent over a half million dollars for 1 349 power sprayers and over $600,000 for irrigation equipment.

f. To handle the crop required an investment of $200,000 in field boxes and to haul the crop to market required an additional investment in trucks of over $300,000.

g. To pack this crop required $2.2 million for wrapping paper and packing boxes. Additionally, $984,000 was expended in the form of brokerage fees.

These figures do not include tractors bought, even though 154 small ones were purchased for $94,000.

IMPACT ON ECONOMY

The fact that the economy has been affected is no longer questioned by those actively involved. If money has a multiplier effect of 7, as some economists claim, the total impact would have been $224 million. More conservatively, with a multiplier effect of 3, it could have amounted to $96 million in impact on the economy. The real impact, however, can only be measured in terms of new bathrooms, remodeled homes, refrigerators, new homes, etc. Or, perhaps the full impact cannot be measured unless one could evaluate the contribution that boys and girls from these families will make to society as a result of their securing additional education.

You might ask the question, what has happened since? Hectares have declined to approximately 283; however, 202 ha are being grown in adjoining districts and states by many of our ex-producers due to climatic locational advantages. We have mechanized, changed cultural practices and varieties. Income has ranged around the $4 million mark yearly in the mountains and younger producers with large areas are replacing the older ones. If it folded tomorrow, the results on peoples' lives would have been worth the effort.

Sometimes in areas with limited resources, we fail to recognize that restrictions can also be unused resources, water, climate (cool nights), native vegetation, etc.

Certain species of plants are native to higher elevations. Among these are three species of rhododendron—*catawbiense, maximum,* and *carolinianum.* Also there is mountain laurel (*Kalmia latifolia*) and several species of native azaleas—all of which can be transplanted from woods to lawn. Competition from overgrowth of other plants has caused distortions which make them unsalable. They need to be "cut back" and transplanted to fields, then in 4-5 years dug, burlapped, and shipped to market. Over the years the demand for the plants has been responsible for a depletion of available plant material. This situation makes it necessary to look at methods of propagation that can be used to obtain field stock. Efforts to propagate from cuttings have not been as successful as with hybrid rhododendrons and azaleas. In October, 1974, research work was started by sowing seed in several types of media. These were transplanted to sectionized flats on December 5, 1974, and had achieved 5-8 centimeters of growth by February 10, 1975. Later they were transplanted to varying types of soil mix and by November, 1975, had grown to heights of 30-46 cm. These were transplanted to fields in 1976, and the results look promising as a source of field stock.

Over the past few years most of the production has been limited to one county, due primarily to: (a) producers who started the enterprise, developed their own market and (b) in many other areas where the enterprise could flourish, producers have limited knowledge as to potential and are not willing to wait 4-5 years for payday.

In order to expand the enterprise a special demonstration project aimed at helping limited resource farmers increase income was started in 1973 in a small mountain community. There are 100 families, with 60 making less than $5,000 per family per year and one-third making less than $3,000. (Only 8 families sold $250 of farm products per year.) Their background was one of working in the pulp and lumber industry. This project is a cooperative one between North Carolina State University, A & T State University, and the Tennessee Valley Authority. Ten thousand dollars was set aside per year for five years to provide funding for purchase of "cut-back" stock (up to 2000 plants per year per cooperator). Thus, a given cooperator by setting out 2000 plants per year with 80% saleable plants, could gross $4,800 per year at today's prices. That is as much or more than many make per year now. Only three families would agree to planting stock in 1973. This year 23 (almost one-fourth) put out plant material and the waiting list is growing. Additional demonstrational plantings were set up in several counties.

Some people estimate that we have the potential for a $10 million income from these plants. The impact on people in a community whose incomes are so low that only poor housing exists, would be significant. As more people get involved it is necessary that we develop technology to insure success. This we have, and are doing, with applied research plots on rates of growth resulting from different rates and types of fertilization. Income from ornamentals was $3.6 million in 1975—up from approximately a half million dollars 20 years ago. An associated income from greenhouse production was at a conservative figure of $5.6 million in 1975 as compared to nearly zero in 1959.

These enterprises represent only part of our efforts to integrate horticultural crops into an otherwise cattle and tobacco economy of a few years earlier. In the meanwhile, it is interesting to look at what has happened to this economy: beef cattle have increased from $6 to $12 million,[3] dairying has jumped from $8 to $24 million, and tobacco has increased from $13 to $18 million. Other fruits and vegetables have increased from $5.1 to $15.2 million through the addition of crops such as trellised cucumbers—another new enterprise which is approaching the $1 million income level.

In finding enterprises that can utilize existing resources, it pays not to overlook our streams which can grow trout, and which in 1975 accounted for a gross income of $2.3 million. Recent research on potential indicates that if expansion is to go much beyond present levels, to a level large enough to supply a large processing plant, a big jump in production is necessary. This may not be feasible even though this research does indicate a profitable margin between costs of production and present market prices which are derived from sales from catch-out ponds, from dressing and selling to restaurants in limited amounts which supply the demand from the tourist industry.

During this presentation we have looked at enterprises that have been integrated into a system of farming common to mountain-type agriculture. The resultant effect has been to increase total farm income from $58.9 to $123.3 million in 17 years (current dollar comparisons).

[3]All income comparisons in this presentation are in terms of current dollars and from county Extension yearly estimated income.

If we have had any degree of success in increasing income within the agricultural sector of our economy in western North Carolina, it is due to several factors. Some of the more important ones are:

a. The involvement of lay people in an analysis of the agricultural situation in our area and in projecting future direction.

b. Agents' and specialists' review of production information from other states and visits to these states to observe production practices, where applicable.

c. The cooperative involvement of the Agricultural Extension Service of North Carolina State University and the Tennessee Valley Authority in fertility demonstrations that has resulted in finding the best rates of N, P, and K to use on crops.

d. Cooperative involvement of the Experiment Station, the Extension service, and the Tennessee Valley Authority in research on types of fertilizers.

e. The involvement of specialists and agents in getting lending agencies, including local business leaders, to finance and establish sufficient markets to handle various enterprises.

f. The use of method-demonstrations to teach production practices.

g. The involvement of North Carolina Department of Agriculture in soil testing and marketing.

h. Publication of technical and popular bulletins to provide production information and to promote enterprises.

i. The involvement of fertilizer, seed, and insecticide dealers, as well as dealers of other inputs, so that these inputs would be available as recommended.

j. Intra-departmental involvement of all researchers and specialists necessary for successful enterprise acceptance and success.

k. The involvement of news media in dissemination of information.

l. Most importantly, the dedication of agents to bettering the lives of farm families and the cooperation of those same families in conducting applied research and result on method demonstrations.

The hardest question we have had to face, and still face, relative to new enterprises such as these is the potential for future production of the crop or expanded production. In this area, market feasibility studies are needed which look at competition from other areas, future labor supply, quality that can be obtained in our area as compared to others, the economic advantage of location to market, etc. We, in most instances, do not have the advantage of these types of studies and start out on a "sell where you can basis." In spite of the disadvantages of not knowing the future, we believe that it is our responsibility to provide educational leadership to farm families, so that incomes may be enhanced.

DISCUSSION

R. Gorman (Washington State, USA). In Washington we have worked with several native American Indian tribes to try to increase their income. However, we met with difficulty in trying to get former cattlemen and timber operators to go into intensive horticultural productions. I was wondering if you might explain if you have had this problem and how you dealt with it?

Robinson. You mean as far as the farmers in western North Carolina or as far as the Indians? We have a Cherokee Indian Reservation that we work with, too. In general, as far as farmers are concerned, I think, acceptance to any change is like it is with most of us—a relatively slow process because, in particular, if you look at our age structure, only 25% are under 45 years of age; so you do find change hard. I would say that the problem we faced was that of getting people to accept new enterprises, and basically, the way that we did it was through two things. One was dedication of the agent in just plain selling and talking a man into this: "One of these alternatives seems to provide you a better opportunity to improve yourself." The second is to make sure that when he does get into something that (1) he can sell it and (2) he can make a profit out of it. And to this end they have been willing to devote untold hours of time at night, and even in some instances helping haul produce to market to make sure that in the beginning it was successful. I think perhaps one of the greater things we have learned over the years whenever you start out working with any farmer, particularly a small farmer, is that his first experience with you be a successful one. If it's a grassland demonstration, make sure that that one demonstration is going to show some results. This, then, establishes confidence in the agent or the researcher or the specialist.

E. Over (New York, USA). You mentioned the use of advisory committees in getting farmer input and then later you talked about the one-on-one situation. Have you found that as farmers become involved that they then become agents? The one-on-one almost looks like an impossible task. Do you get a multiplier effect soon and, if so, how soon did it come and how broadly did it diffuse?

Robinson. Well, that's a difficult question to answer. Let me express my thoughts on it then I'll ask Harry Silver to expound on it, because he's been involved in county work and in supervision for quite a number of years. First of all, when I refer to the use of advisory boards and subcommittees, this is in planning and implementing and evaluating the various enterprising programs and getting ideas from them. And when I talk in terms of one-on-one situation, I'm talking

about the involvement of farmers and getting them to accept these new enterprises. We have found, at least to begin with, that this absolutely requires one-on-one: First of all, to get him interested and, second, to follow-up enough to make sure that it's successful. Then you do get a multiplier effect. You get the spread of word in the country store; the fact that a farmer put out an acre of tomatoes and made so many dollars begins to get some interest. Then you begin to get a cumulative effect for the agent in which, if he's setting up a demonstration, he will have quite a number of people who come out of curiosity or otherwise. So his work, as he gets started into it, is not as much one-on-one as it was originally. But we have not found any way we can get enterprises started unless we do go one-on-one.

Harry Silver (North Carolina, USA). The expansion of an enterprise from a one-on-one basis is generally started with a farm demonstration. If you're very careful in selecting the original cooperator who is accepted as a man of recognition in the community to begin with and if that demonstration is successful—and that's very important—then you do get a tremendous multiplier effect. Without that, it would be impossible for the agents in western Carolina to reach the farmers that they have reached introducing expanding new enterprises. It might be of interest to you that we have from 1 1/2 man-agent equivalents to work in the field of agriculture as well as community resource development; about 5 would be the highest man equivalents we have in a given county.

115.
Livestock Production and Forestry on Western Hill Country

W. Mosher

Extension Service, Oregon State University, Douglas County, Oregon, USA

Subterranean clover (subclover) (*Trifolium subterraneum*) was introduced into Douglas County, Oregon, in 1935. With adequate rainfall, it has been nearly the "perfect" plant in pasture production on our hill soils and under our mild winters. Its use has raised hill-pasture carrying capacity from 3/4 ewe to 6 ewes per ha. Subclover can fit other winter annual crop-producing areas of the world. Our use of it is patterned after New Zealand and Australian pasture improvement.

Subclover is a winter annual legume. It originated in the Mediterranean, was introduced accidentally into Australia, and later imported into the United States.

On the West Coast of the United States is a relatively small winter annual area between 38 and 48 degrees latitude. This is an area with from 35 to 200 cm of winter rainfall, dry summers, and relatively mild winter temperatures, well-adapted to winter annual grasses and legumes. Within Oregon this area extends from the Cascade Mountains to the sea coast. In California the area extends from the coast range to the Pacific Ocean in the north and from the Cascade and Sierra Nevada ranges westward to the coast in central California. It extends south about to Sacramento and San Francisco.

The rainy season starts in mid-September or October and continues through the winter months, with the last rainfall coming from April to June. The summer months are dry, with little effective rainfall. Average temperatures vary from a high near 38° in the summer to a low near −6° in the winter time with colder temperatures at higher elevations. There are snows at higher elevations but only occasional snows at the lower elevations.

Most of this area is rolling-to-steep hill lands, with narrow valleys. Soil depths vary, with large areas of shallow hill soils 30 to 100 cm deep and slopes to 40 degrees. Some of the area is covered with Douglas fir (*Pseudotsuga menziesii*) and other conifers, but other areas of thinner soils are open native grasslands, brushlands or hardwood forests. Native grasslands and fields are intermixed in these hardwood and softwood forests. Native annual grasses include crested dogtail (*Cynosurus cristatis*), Mediterranean barley (*Hordeum hystrix*), ripgut brome (*Bromus rigidus*), soft chess (*Bromus mollis*), and some of the annual fescues. Very few native legumes exist in this area.

My own association with subclover has been in Douglas County since 1948, where during the 1940's and early 1950's thousands of ha were seeded to

subclover and improved grasses. On fertile soils the pasture did well but on the low fertility, shallow soils little improvement was achieved. In 1957, Cooper of Oregon State University established experiments to evaluate effects from phosphorus, sulfur, and potassium fertilizers and the relationship between soil and plant analysis and response from these nutrients on several hill soils in Douglas County. The response from these trials (Table 1) and others showed the need for fertilizer and the benefits achieved by applying it on these hill soils.

TABLE 1. The effect of phosphorus and potassium on yield of subclover, Kg/ha

	K_0	K_1	K_2
P_0	1 325	1 134	1 368
P_1	3 425	4 279	4 094
P_2	3 628	4 646	5 268

P_1 P_2 = 30-60 kg/ha.
K_1 K_2 = 30-60 kg/ha.
All treatments received 35 kg S/ha.

Soils are moderately acid with a pH average of about 5.7. Yield data and forage analysis showed that on most soils phosphorus and sulfur were both limiting. In a few cases we were able to demonstrate that potash also could be limiting—particularly on hay fields. Later work showed a need for molybdenum on these pastures. From 20-28 kg of P annually and 35 to 45 kg of sulfur per ha annually made tremendous increases in forage production. Production was increased from 1000 kg dry weight per ha annually of a very low quality forage to 4 to 7 thousand kg dry weight/ha/year of a highly nutritious forage. During this same period work in California by Jones *et al.* (1970) also showed the value of phosphorus and different forms of sulfur in fertilizing California annual pastures.

One of the initial problems with establishing subclover on hill soils was proper inoculation. No native legumes cross inoculate effectively with subclover in most of the area. In Douglas County we were fortunate in that proper strains of inoculum provided by Oregon State University effectively nodulated the subclover. In succeeding years inoculation materials have been produced commercially and Oregon State University ceased to make subclover inoculum. Most of the commercial inoculum has been quite satisfactory but there have been some exceptions. Recent work in California at the Hopland Field Station and in the Sacramento Valley indicates that there are superior strains of rhizobium which are helpful under more difficult conditions in establishing subclover.

Recent work in California by Jim Street, Extension Range Specialist, University of California, Davis, with varieties of subclover also has been very helpful in establishing clover on some of the more marginal areas within its range. Lower rainfall areas and areas of shorter rainfall seasons have demanded shorter season varieties of subclover than the medium-to-long season varieties generally used in Douglas County and throughout much of western Oregon.

The initial emphasis in Oregon was planting subclover on old crop fields. When subclover was established on many of these fields the emphasis was switched to the native grasslands. When a good share of these were seeded the farmers began clearing hill land of brush and trees with bulldozers. Trees and brush were pushed into piles and burned, the ground was worked, seeded, and fertilizer applied. Pasture yields have increased four to five times with a great improvement in quality. Costs under present-day conditions for clearing, seeding, and fertilizing of brushland on the hills is averaging around $226 per ha.

Disturbing the soil on these hills has not resulted in erosion. Early fall rains are relatively gentle and growth of seedlings is rapid. The soil absorbs the moisture very well, settling the generally clay type soils so that later heavy rains do not cause serious soil erosion. After the initial seedling year the cover of grass and clover eliminates significant erosion except for areas where slips occur. These occur with equal frequency in areas covered by brush and trees and grasslands.

Some areas are too steep to clear with equipment or to work the soil. Spray programs to kill the brush have been followed with burning, seeding, and fertilization. Thousands of ha had been seeded in the past with low rates of seed (5 kg/ha) of subclover, with little success. Almost no subclover establishment was observed under these conditions. In 1967 experimental work (unpublished) indicated that pill bugs (*Armadillidium vulgare*) were eating the cotyledon as the subclover germinated. Granular Diazinon insecticide (2 kg/ha) was applied to try to control the bugs, with little success. However, additional work showed that a high rate of seed (20 kg/ha) did provide enough plants for successful establishment of clover. Removal of the dead material by fire was helpful in seedling establishment, and fertilizer was essential. Seeding was done late in the season so that germinating seeds were not exposed to hot dry weather which destroys them before they become established.

With high seeding rates (20 kg/ha) approximately 20 successful plantings (each 20-50 ha) have been completed in Douglas County. This seeding was done by airplane or helicopter making proper inocalation more critical. Work in California has shown the benefits of seed pelleting but this has not been

necessary in the main area in Douglas County. Careful and heavy inoculation of the seed and usually the addition of soil from a good subclover area has been successful in most cases in maintaining viable rhibozia on the seed under these more difficult conditions.

With the greatly increased forage production, increased number of livestock to utilize the forage produced became the next step in the program. One of the major problems in utilizing this forage has been that about 80% of the total forage is produced during about four months in the spring (Fig. 1). Subclover starts with the rains in the fall, makes some growth through the winter months, and puts on a big burst of production in the spring. When the rains cease in summer, the subclover dies. The forage produced during the fall, winter, and early spring is highly nutritious, and dry residue left is adequate feed for ewes or cows in summer and early fall. With high production only during the spring it becomes necessary to manage intensively to utilize the feed for a 12-month feeding program for livestock. One obvious solution to the problem of utilizing the feed efficiently is to cut hay. Subclover does make a very adequate hay if put up properly.

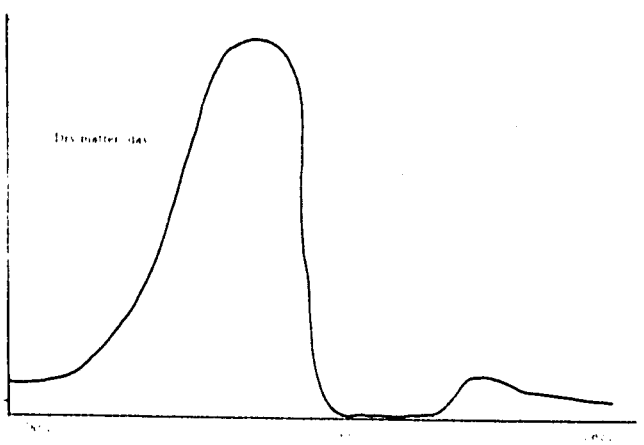

Figure 1. Pasture production curve, subclover--Oregon.

The Douglas County hill area is very well adapted to both sheep and cattle production. To utilize the forage an understanding of the nutrient needs of the animal is important. Levels of nutrition at various stages in the production cycle of the animal have a great influence on the animal production (Fig. 2). Calving or lambing dates can affect forage utilization. The kind of animals run on a pasture can have a great influence on how efficiently the forage is utilized.

Bedell (1971) at Oregon State University demonstrated that feeder steers on spring pasture, with no supplemental feed, gained about one kg per day over a grazing period from March 23 to August 8.

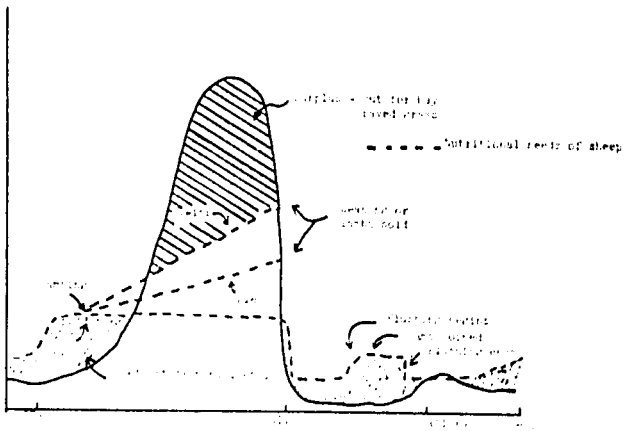

Figure 2. Nutritional needs of sheep vs pasture production curve.

Total live weight gains for the grazing seasons varied from 500 kg/ha to as high as 1 000 kg/ha on various treatments and years. Sheep gains were lower, but ewe maintenance and lambs too young to do much grazing early in the season probably contribute to this. In neighboring Coos County, Oregon, 2.9 and 5.9 ewes with lamb per ha were set stocked on hill pasture to demonstrate the difference in individual animal gain and total gain per ha. At these stocking rates no difference was shown in individual animal gain between low and high stocking rates but the gain per ha was almost double.

Combination pastures of subclover and perennial ryegrass are difficult to overgraze, making management easier. Animal weight losses would become excessive before any serious overgrazing damage was done to the pasture. Heavy grazing of subclover-ryegrass pastures results in better pasture growth in succeeding years, because removal of most of the vegetation from the stand each year permits better clover germination the next fall. With proper fertilization, subclover responds with a high level of production and at the same time provides considerable nitrogen for growth of associated grasses. Higher stocking rates provide more feces and urine on the pasture, which again provides more nitrogen for additional grass and clover growth. New Zealand research has indicated that the nitrogen in a single sheep urine patch provides an effect equivalent to about 100 kg of actual nitrogen per ha. With heavy stocking, urine patches are relatively well scattered over the pasture and the resulting impact of fertility increases grass and clover production.

In addition to benefiting the pasture, a number of other benefits occur from high stocking. Probably the most important is increased livestock production. Most studies indicate that as long as the total productive capacity of the pasture is not exceeded that the saleable products increase with increased stocking rates. While production per animal may decline

slightly, total production per ha increases dramatically as stocking rates are increased. In Oregon, currently, we feel the breaking point is between 6 and 9 ewes/ha. The influence of stocking rate on production has been well demonstrated by work in Australia and New Zealand (Arnold, 1965; Suckling, 1964) and by some current work in the United States. If most ewes produce twin lambs, this increases the livestock utilization during the spring months when the pasture is at its maximum rate of production. To illustrate how twinning can affect economic returns from such an operation, Dr. E. Gene Nelson, Extension farm management specialist at Oregon State University, and the author theorized on the impact of a high lambing percentage and a high stocking rate on income compared to low lambing percentage and/or low stocking rates (Table 2). Table 2 shows the difference between how a profitable operation and a marginal operation is influenced by an increased stocking rates and/or higher lambing percentages.

TABLE 2. Return to land, labor, and management with pasture development program

Lamb Crop Weaned	Ewe Stocking Rate per ha		
	3½	4	5
		(S/ha)	
90%	8.26	27.64	47.04
140%	72.76	113.64	154.54

In our region sheep have two advantages over cattle. Sheep have a much higher potential level of reproduction efficiency and require a shorter period to grow young from birth to market weight. Sheep fit quite well with the pasture production curve of subclover-rye grass pastures. Some sheepmen are running 6 ewes/ha with a 140% lamb crop and individual cattle ranchers are approaching a cow per ha with 95% calf crop. Fall calving makes more efficient use of the forage than spring calving. When the calves are born in the early fall they are big enough by the time spring growth comes to utilize the forage quite well. The forage dries up before spring calves are ready to use a great deal of it. Many of our ranchers are keeping over calves to "long yearlings," letting them graze a second season on pasture and selling them about the time the pasture dries in the spring. This type of operation has proved quite successful.

In Douglas County stockmen have used subclover to convert hill lands from low carrying capacity to high carrying capacity. Today we know how to grow large quantities of good forage. For the future we need to work on marketing that forage through livestock. Growers must recognize that the only use for animals in this program is to change forage to a marketable product.

Individual sheep growers in Douglas County are approaching 200 kg of live weight lamb sold per ha annually. These levels of production can be increased considerably over the coming years with a continuing research program. Lambing percentages of 200% are possible. Sheep farmers in England and Scotland are producing 200% plus lamb crops with 500- and 600-ewe flocks by proper breeding and management.

If they can do it so can we. Our potential production far exceeds what we are doing today. The future looks bright!

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DISCUSSION

F. Horn (Oklahoma, USA). What is the cost of doing this and what is the trend in recent years? Cattle have been losing some of their glamour in recent years in the Midwest.

Mosher. The costs of putting in this land varies tremendously with the slope—with the vegetation that's on it. In the heaviest places that we're going this is land that would be perhaps as steep as 30°. On land that would be heavily covered with hardwoods, pretty big trees, we're using D-8 caterpillars. The bigger the "cat," the faster you clear it, the easier it works. We're spending about $250 per ha in the worst places to do the complete job—this is the clearing, the seeding, and the fertilizing.

Horn. You said some of this land is poorly utilized. Is any of it reverting and, if so, what's happening in terms of soil erosion and this sort of thing?

Mosher. Well, I think that some of this land that is being fully utilized is reverting. It's going back to brushland species such as wild rose and poison oak. We're seeing some land come back with hardwood trees such as the black and white oaks. I think that the trend, though, is toward improved pasture.

You do fertilize it, and we're getting people to use it better. We do not run into erosion problems even on native grasslands. The only place where we have erosion is in the flatlands that were laid down by erosion. When we get a particularly heavy rainfall in the winter time, sometimes these start to cut. Once they start to cut we have not really been successful in stopping it. I think that I mentioned also that we're talking about an ongoing program and that we're probably bulldozing hardwood trees off in Douglas County perhaps somewhere at about 2 000 acres a year. Our program basically started out on some of the cropland that was fairly well depleted, then it went to the native grasslands and now we're in the heavier brushland. We've still got a long way to go. I don't mean we've got the job done by any means. We have 100 000 acres in; we've got a half million acres that should be in. I think we'd get no argument on this. (There may be another couple of hundred thousand acres in Douglas County about which we might argue a little bit with the foresters.) In western Oregon we think we're talking about something like 2 million acres that should be in improved pasture. If you include California, I suppose we may be somewhere up in the 4 to 5 million acre range.

G. Jung (Pennsylvania, USA). I want you to go back to an instance in which one of the ranchers you talked about had less animal gains than his neighbors. You were concerned about the fact that you couldn't explain why this one operation was not as productive as some of the others that you were working with. You looked at mineral deficiencies to see if it could be explained on that basis. It couldn't be and we sorted out the fact that one major difference between this particular operation and the neighbors' was the fact that he was basing his on orchardgrass and the neighbors were using ryegrass. Have you made other observations on that? Is it really the species—the grass species—that was causing the lower gains? We talked about the fact that this might be related to energy.

Mosher. We haven't done definitive enough work to really say whether it is or isn't, but I don't think that there is that much difference in grass species on gains, with the exception of the work that Tom Bedell did. He was able to demonstrate that fescue subclover pastures would produce later into the season and probably produce more cattle gain than ryegrass and subclover. Most of our hills won't grow long-lived perennial grasses, with the exception of perennial ryegrass, and practically all of our pastures are based on perennial ryegrasses. Since that time, I think we've also become much more aware of the selenium weed. We've actually gotten liveweight gain with selenium. Of course, we know that it's involved not only in liveweight gains but also in reproduction, disease, tooth wear; I think that there are a lot of things involved. We've had some very interesting experiences and achieved increases in liveweight gains on some of these properties simply from the administration of selenium. We need to know a lot more about mineral nutrition, particularly minor element mineral nutrition, under a very intensively managed pasture and very highly stocked pastures. The higher we go, the more production we get, the more dilution effect we get, and I'm sure that this could be a factor.

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Some Aspects of Sheep and Beef Cattle Production on New Zealand Hill Country

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New Zealand is largely a land of mountains and hills with 13 million ha of pastoral land, of which approximately 4.5 million ha is hill country (both wet and dry) supporting 31 million ewe equivalents, or 7 stock units (1 breeding ewe = 1 stock unit) per ha. Dry hill country has an average carrying capicity of about 4 ewe equivalents, whereas the wetter and easier hill country carries about 10 ewe equivalents per ha (Brougham, 1973). The hill country sheep and beef farms in the North Island now carry about 17.8 million sheep, or 64% of the North Island sheep and 73% of the beef cattle (Ward, 1972). Hill country farming, therefore, dominates the New Zealand sheep and cattle industries in total area, stock carried, and as a supplier of stock to downland farms.

Much of New Zealand's hill farming land is steep and originally developed from dense high rainfall forest. Typically, 5 300 stock units are carried on hard hill country farms situated mainly on the East and West Coasts and the Central Plateau, while 3 600 units are carried on the easier North Island hill country farms. On these farms, replacement ewe hoggets (yearlings) comprise about 28% of the total sheep with 40% of the average 270 single-suckled beef herd being 2½ years old and older, and 12% weaner heifers. Most farms are subdivided into 15 to 30 paddocks. Permanent pastures of grasses and legumes are used almost exclusively. Inorganic fertilizer is applied by aircraft, but nitrogen fertilizer is not used to any extent, reliance being placed on clovers to supply nitrogen. Romney, Perendale (interbred Cheviot × Romney), or Coopworth (interbred Border Leicester × Romney) breeds predominate in ewe flocks and Angus and Hereford cattle in beef herds. The main sources of farm income are wool (36%), lambs and cull ewes (30%), calves and cull breeding cows (30%).

There are three essentials for efficient animal production from grazing sheep or beef cattle on these farms:

1. A large amount of nutritious pasture needs to be grown.
2. This feed needs to be efficiently harvested by grazing animals.
3. Consumed feed must be converted efficiently into saleable animal products.

There is a large potential to increase production in New Zealand hill country. Unfortunately, the maximum productive capacity has not been adequately tested, although there is a potential to increase carrying capacity by at least two times above present levels, or by an additional 40 million ewe equivalents. On the better class land with good rainfall patterns, pasture and animal production could approach that on the cultivatable and rolling country.

Factors important to the realization of this potential include:

1. Effective grazing management to give more pasture production, better utilization, and improved feeding of stock.
2. An increase in the amount and vigor of ryegrass and, particularly, the legume content of pastures, and possibly the introduction of new pasture species better suited to hill country environments.
3. The introduction of genetically superior sheep and cattle and, with development, the retention of more young growing animals to convert pasture directly into meat and wool, instead of breeding ewes and beef cows.

Thus, factors involved in the successful economic future of New Zealand hill country are closely related to good stock husbandry. They include feeding and grazing management, the breeding of stock, and general management skills.

PASTURE PRODUCTION

Few assessments of pasture production have been made on hill country. Pasture production is highly variable with levels of dry matter (DM) up to 9 000 kg/ha being recorded on dry hill faces, and 13 000 kg DM per year on wet hill slopes (Radcliffe *et al.*, 1968; Gillingham, *pers. comm.*).

An indication of the pattern of average pasture production measured by the trim and regrowth technique (Gillingham, *pers. comm.*) for two hill soil types at Whatawhata is indicated in Fig. 1. For steepland silt loam soils, average production was 7 850 kg DM/ha/yr and on volcanic ash soils 9 020 kg DM/ha/yr. Between-year variation is highest in the autumn and least in the spring, reflecting the influence of soil moisture levels.

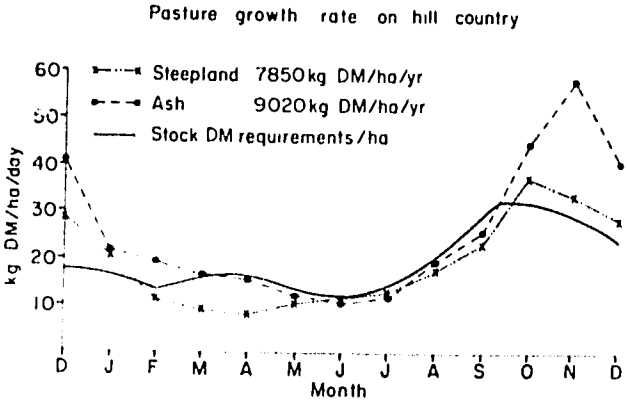

Figure 1.

If the total feed requirements (Jagusch, 1973) of typical numbers of breeding ewes (45 kg live weight), cows (450 kg), and ancillary stock grazed at 11 ewe equivalents/ha is superimposed on the average pasture growth curves, it is evident that:

1. There is a large surplus of pasture growth in late spring and the time at which this occurs is reasonably predictable.
2. In the late autumn and winter, stock feed requirements can exceed the variable autumn pasture growth, particularly on steepland soils. Winter pasture production can strongly influence maximum stocking rates when little or no supplementary feed is used and no planned feeding of stock is practiced.

GRAZING MANAGEMENT

A grazing management system is required to achieve both high stock and pasture production within the constraints of limited numbers of permanent paddocks and the need for continued development of land.

Few management trials have been conducted in New Zealand hill country (Inglis, 1965; Kissock, 1966; Collin, 1966; Suckling, 1959, 1975; Smethan, 1973) to define the effects of class and genetic merit of stock, aspect (sunny or shady), grazing method, grazing intensity (continuous/infrequent and lax /hard), fertilizer requirements, or of supplementary feed on pasture and animal production.

Rotational Grazing

Nevertheless, there appears to be considerable potential to increase output by adopting more intensive planned rotational grazing with higher stocking rates (Campbell, 1969; Hight and Wright, 1972) on pastures where ryegrasses (*Lolium* spp.) and white clover (*Trifolium repens*) are present. An outline of this rotational grazing system (Smith *et al.*, 1976), which has been used at the Whatawhata Hill Country Research Station and on 300 private farms, is given in Fig. 2. Lambs are weaned at an average age of

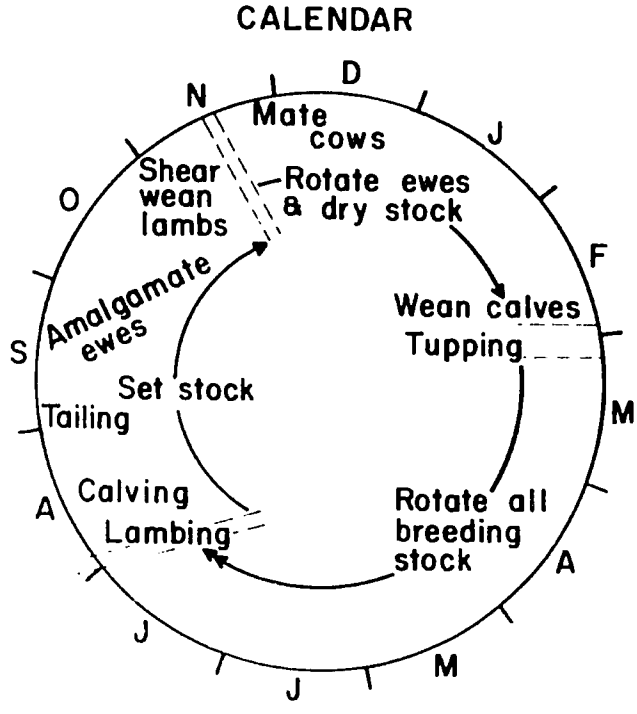

Figure 2. Grazing program.

10–12 weeks in November–December, and the ewes then commence on a rotation of about 3 days per paddock, allowing a 35-day interval between grazings, and at a stocking rate of 300 to 500 ewe equivalents per ha. Early weaning and shearing to assist rapid recovery of ewe live weights is being recommended rather than only attempting to flush ewes pre-mating when suitable feed is seldom available. The rotation of the ewes continues through mating until prelambing (mid-July). At this stage the rate of rotation is increased to even-out available pasture, provide a "short bite" (5 cm), and to increase feed intake to 1½ times maintenance for the lambing ewes. The ewes are set-stocked from about 7 days before lambing commences until weaning, with ewes and lambs being progressively grazed at a higher rate in late spring in anticipation of excess pasture growth. This also allows a greater area to be made available for young sheep and breeding cows. During periods of rapid pasture growth, set stocking does not result in close and continuous defoliation so that in spring pastures can remain at an optimum stage of growth over lengthy periods.

Beef Cattle

Beef calves are weaned at an average age of 150 days (mid-February) and in-calf cows are then joined with the main ewe mob in the rotation. In this way, a main grazing group of about 80% of the stock units, or up to 7500 ewe equivalents, might be formed and a grazing interval of about 35 days can

be adopted within the 15 to 30 permanent paddocks usually available. As cows approach calving (July–August) they are removed from this main grazing group and "rationed" pastures, which have been leniently grazed from late autumn, behind one-wire electric fences. As the cows calve, they are either moved ahead of the uncalved group on a rotation length reduced from 35 to about 15 or 20 days as pasture growth increases in late spring, or set-stocked in paddocks where abundant pasture is available. The aim is to offer cows the maximum level of pasture post-calving to ensure a short calving to first estrus interval. At the commencement of mating (October–November) cows are formed into single-sire mating groups and grazed on the special beef area or on paddocks where ewes and lambs were grazing.

Replacements

The young sheep and replacement heifers are grazed preferentially from weaning until first mating. Lambs are drenched with an anthelmintic at weaning and transferred to areas previously grazed by beef cows over the winter–spring period. These areas are presumed to be relatively free of viable internal parasite larvae (Brunsdon and Adam, 1975; Brunsdon, *pers. comm.*) and tend to have a higher legume content than those pastures more closely grazed with ewes and lambs. The weaned lambs are shorn and rotationally grazed at a low intensity to permit selective grazing over this "cattle" area, but do not regraze any paddocks that season. They are then grazed ahead of the mature ewe and cattle group until lambing time, when the hoggets are set-stocked until the spring flush of pasture growth again enables a higher stocking to be adopted. Replacement heifers are either intensively grazed behind electric fences on the better pastures or are rotationally grazed with or separate from the ewe hoggets until their first mating at 14 months of age.

Rotation Length

Rotation length for the main mob is increased or reduced according to visual assessments of the amount of pasture available, expected rates of pasture growth, rainfall, stock feed requirements, and the conditions and performance of the animals. Thus, grazing intervals of 40 to 45 days in the winter or 20 to 25 days in the summer may be optimum.

Subdivision

The optimum degree of subdivision at any given stocking rate or stage of land development has not been defined, but if sheep and cattle are grazed together when their feeding levels are similar, there is then a reduced need for subdivision. However, there are distinct differences in pasture production and composition between sunny and shady aspects (Gillingham, 1974; Suckling, 1975). Differential fencing of sunny from shady aspects enables the shady faces to be grazed more in summer and sunny faces more in winter, so that over grazing of palatable legumes is avoided between late-spring (October) and the autumn. The use of single-wire electric fences (Hight and Wright, 1972; Parker, 1972) also permits the rationing of limited pasture to beef cows over the winter–early spring, appears to give increased pasture utilization, encourages rapid pasture recovery and reduces the need for supplementary winter feed. Treading damage (Edmond, 1966) under high soil moisture levels is confined to small areas. As management is intensified more grazing control with electric fences appears justified, particularly with beef cattle.

Benefits of Rotational Grazing System

Some of the potential benefits are:

1. Better planned feeding of stock in relation to their feed requirements, particularly at higher stocking rates and in periods of pasture shortage. A higher and more even utilization of pastures on a whole-farm basis over the summer–autumn period is an important feature of this system compared with set-stocking or non-systematic movement of stock. Livestock adjust their grazing habits to the herbage available, and at high stocking rates, a very good "clean up" of pasture is achieved. With intensive integrated grazing of cattle and sheep, the less palatable weeds and unproductive pasture species also are kept under control.
2. Between-year comparisons of stock performance indicate improvements in the rate of growth of ewe hoggets, pre-mating ewe live weights and fertility, with an increase in the percentage of replacement beef heifers which attain puberty and calve at two years of age, and in subsequent years, within a 45-day period. These factors have an important influence on profitability.
3. Less supplementary winter feed in the form of hay, silage, or crops has been required for beef herds in those areas not experiencing severe winters. With planned feeding, surplus pasture growth is more readily observed in the late spring and, if practical, it can be conserved before dry soil conditions delay the recovery of pastures cut for hay.
4. When ryegrass and clover species are present these become more prevalent and the incidence of weeds reduced. There appears to be better pasture growth in the late summer, autumn, and early spring than under set-stocking. The increase of legumes is of basic importance, for with few clovers the build-up of soil fertility is slow, large areas may suffer from nitrogen deficiency, and the feed quality of autumn pastures is likely to be below optimum for young growing animals (Hight and Sinclair, 1967).

5. Recent recommendations for the effective control of internal parasites (Brunsdon and Adam, 1975) in susceptible weaned lambs and calves by strategic drenching with anthelmintics and shifting to pastures of improved feed quality where viable larval populations are low become more practical to operate. Increased post-weaning growth rates result. This may have important carryover effects on subsequent ewe live weights and fertility (Hight and Jury, 1976), and on both in-calf rates and the spread of calving in beef cattle. There is also more scope for young animals to selectively graze pastures.

6. The high concentrations of stock required in late spring to control weeds and pasture roughages, or in late autumn (May) for the close and even grazing of areas before aerial application of seed, and the subsequent treading in of this seed, become easier to manage within the limitations of the paddocks usually available on hill country farms.

7. As hill country land is developed to higher producing pastures, a complementary approach to the attainment of higher efficiency from increases in ewe and cow fertility is to finish more lambs for slaughter at heavier weights, or to substitute younger growing cattle for beef cows. More direct and efficient conversion of pasture to meat and increases in production and profit can then result (Large, 1970; Hutton, 1963). The optimum mix will depend on market realizations, farm and farmer adaptability. Under the grazing system being recommended, the provision of special feed for growing or finishing stock becomes more feasible as fewer paddocks are occupied at one time over the summer-autumn period by mature breeding animals.

Grazing pressure and pasture utilization can be varied at different times of the year so that young growing animals achieve satisfactory food intakes and live weight gains.

8. More efficient use of labor, which is both costly and in limited supply, results because staff know when and why stock are to be moved. The visual assessment of pasture available, with a knowledge of animal requirements, enables some objectivity to be introduced to planned grazing management in a way that can be understood by farmers.

Many possibilities for refinement of this management system are available but maximum production seems unlikely to be achieved on hill country until a combination of high stocking rates and genetically superior livestock are grazed on improved pasture adequately topdressed with essential nutrients and some intensive planned rotational grazing of stock is practiced. Unfortunately, there are limited experimental data available to support this thesis for hill country conditions or on the influence of class of stock, grazing method, and other variables on productivity. Nevertheless, the grazing system outlined is providing a workable framework for the application of existing grazing management knowledge to hill country in the North Island of New Zealand.

LIVESTOCK PERFORMANCE AND ANIMAL BREEDING

Improved fertility in relation to nutritional requirements through better grazing management is the key to increased productivity from existing livestock, but further increases in per animal performance of the order of at least 50% are possible through the application of available animal breeding knowledge. The genotype of the grazing animal sets the upper limit to production attainable from improved management.

Beef Cattle

For efficient production from beef breeding cattle in New Zealand, heifers should ideally first calve at two years of age, and thereafter achieve a regular and concentrated calving of less than 45 days. Structurally sound cows should be capable of weaning calves without assistance to high weaning weights (250 kg at 160 days), and of producing animals which have rapid post-weaning growth rates to slaughter at about 21 months. Much higher outputs per unit of female stock wintered, or per unit of dry matter consumed, are possible through the organized application of animal breeding knowledge combined with improved nutrition.

Unfortunately, few beef heifers are calved at two years of age and those that are often exhibit unsatisfactory in-calf rates as three-year-olds. In-calf rates of older cows are on average 83%, and there is a 2½ month spread of calving. Many Angus and Hereford cows wean calves weighing less than 150 kg, and this has important carry-over effects on 14-month heifer weights and on the weights of steers slaughtered at 20 months of age. These factors are of considerable economic importance.

Selection Within Breeds

The key to selective breeding within commercial herds is the genetic merit of the bull breeding herds, as about 80% of the potential improvement results from the sires used. There is, therefore, a need in the beef industry for a coordinated genetic improvement program which both identifies and exploits superior genetic material. A National Beef Improvement Service (Beefplan) has recently been further developed and is providing a useful service within the traditional registered bull breeding herd structure, but its widespread adoption and use for effective on-farm selection is likely to be slow. Other genetic programs have, therefore, been sought to supplement and complement Beefplan.

One of these developments is the formation of group breeding schemes. These large-scale integrated breeding schemes (Hight and Quartermain, 1970; Hight *et al.*, 1970; Dalton and Gibson, 1974; Nicoll, 1976) conducted within those commercial farms with large herds, or on a cooperative basis offer many advantages over the generation of sires from smaller unrecorded registered herds. In the cooperative schemes, 2 to 10% of the elite producing cows which have a high maternal ability and/or yearling live weight are transferred from several herds to nucleus units where they and their progeny can be selectively mated, objectively recorded in the same environment, and ranked in order of breeding value. With continuous screening, and the application of efficient selection, these schemes are already offering an efficient means of generating the large number of bulls of high genetic merit required in the beef industry. It may be possible to adopt the principles of these group breeding schemes to other countries, particularly those where artificial breeding is not widely practiced.

An indication of the potential from this approach to within breed selection is provided by the large-scale breeding scheme of the Department of Lands and Survey operated in conjunction with scientists from the Whatawhata Hill Country Research Station. Here, unregistered Angus cows with the ability to wean calves up to 250 kg at 150 days of age (av. 197 kg), heifers weighing up to 320 kg (av. 253 kg), and bulls to 360 kg (av. 288 kg) at 12 months of age have been identified (Dalton and Gibson, 1974). High levels of fertility in both heifers and mature nucleus cows have been attained. These group schemes offer a practical method of utilizing the wide variation between animals within existing cattle breeds and farmer resources.

Crossbreeding

Considerable research in New Zealand and in other countries (Cundiff *et al.*, 1974) also suggests that the use of Friesian (Hight *et al.*, 1973) and Friesian crossbred cows has advantages over purebreds in terms of the number and weight of calves at weaning; the productive value of Friesian × Jersey, Friesian × Angus, or Friesian × Herefords as maternal beef dams (Dalton *et al.*, 1975; Carter, 1975; Baker and Carter, 1976; Hight and Nicoll, *pers. comm.*) being particularly noteworthy. A summary of the performance of these crossbreds in trials recently conducted by the Ministry of Agriculture and Fisheries (Baker and Carter, 1976) is given in Table 1. These crossbreeds appear to give an increase of about 30% in the total weight of calf weaned per 100 cows at mating (productivity), and 20% more productivity per 100 kg of cow live weight (efficiency) when compared with existing beef breeds or exotic crossbred cattle. The Friesian crossbreds had both a high reproduction rate and superior maternal ability as reflected in increased weaning weights. This, together with the effects of heterosis on fertility, has important carry-over effects on the successful mating of heifers at 14 months of age, and on live weights of steer progeny slaughtered at about 20 months (Hight *et al.*, 1973; Everitt *et al.*, 1975). Considerable evidence, therefore, appears to justify the wider use of beef × dairy crossbreds in beef breeding herds which are grazed on developed hill country as an alternative to selection within existing beef breeds. Preliminary results from extensive trials with the larger "exotic" breeds (e.g. Charolais, Simmental) crossed with Angus, Hereford, or Friesian cows indicate that the crossbred progeny are prone to difficult calvings, exhibit later sexual maturity, but have improved growth rates and meat yields.

TABLE 1. Summary of performance of straightbred and crossbred beef cows

Cow Breed or Cross	Productivity	Efficiency
Angus (A)	100	100
Hereford (H)	95	90
Friesian (F)	125	110
A × H and H × A	115	110
F × A	130	120
F × H	130	120
F × Jersey	135	130

Productivity = weight calf weaned per 100 cows mated.
Efficiency = productivity per 100 kg/cow live weight.

Sheep Breeding

In hill country, low growth rates (<0.7 kg/week) from weaning to mid-winter (Hight *et al.*, 1973), and poor pre-mating ewe live weights (40–45 kg)—reflected in a slow onset of estrus and inadequate conception (57%) in-lamb rates (Knight and Hight, 1976), and multiple birth rates, with a 5 to 25% lamb mortality to weaning (Hight and Jury, 1970a, b)—are often characteristic of several breeds and crosses (Hight and Dalton, 1974). Planned grazing management associated with better nutrition and changes in pasture composition are key factors in improving these components of productive efficiency.

A comprehensive animal breeding research program conducted by the Ministry of Agriculture and Fisheries and at universities also has shown that large increases in lamb survival and multiple birth rates, live-weight growth, and fleece weights of existing sheep breeds through the application of selective breeding are feasible under farming condi-

tions in New Zealand (Clarke, 1972; Hight *et al.*, 1975). There is considerable interest in applying this information in a coordinated genetic improvement program to identify and exploit superior genetic material. A National Sheep Improvement Service (Sheeplan) has been developed (Dalton and Callow, 1976), and 25 large-scale cooperative Group Breeding Schemes recently formed (Hight and Rae, 1970). These group schemes now involve over 300 private breeders. In group breeding schemes the highest producing sheep are identified on cooperating farms and are transferred each year to central ram breeding nucleus flocks, where they and their progeny are objectively recorded through Sheeplan and ranked in order of total breeding value. By continually selecting a small proportion of high producing animals from cooperating flocks and applying selection within the nucleus units, it has been possible to quickly establish and maintain nucleus flocks of high merit, to restrict detailed recording to those sheep of above average performance, to compare animals for genetic merit in a common environment, to make more effective use of superior sires, to set higher levels of culling than is feasible in registered flocks, and to generate increasing numbers of rams at low cost. The development of these cooperative group breeding schemes by the farming community, techniques of field recording, data processing, and selection of "easy-care" sheep which give high production with minimum labor inputs (Rae, 1964; Hight and Bignam, 1975), appears to also have application in other countries.

In the Romney sheep breeding scheme operated by scientists from the Whatawhata Hill Country Research Station and the Department of Lands and Survey (Hight *et al.*, 1975) there are a total of 17 000 sheep individually recorded in the nucleus flock. The traits recorded are fertility, lamb weaning weight, 12-month body weight, and fleece weights. Rapid progress has been made in breeding sheep of higher fertility and improved overall productive value. For example, in the present 8 400 nucleus ewe flock, there are 2 700 ewes with lifetime breeding values for fertility equivalent to 150% or higher numbers of lambs weaned without any assistance. Increasing numbers of sires are being produced each year for mating to about 400 000 ewes. Comparative information indicates that the use of rams produced from this nucleus has reduced lamb mortality and increased lamb weaning percentages by about 22%. Ram waste rates have also been markedly reduced.

For social, economic, and genetic reasons, there is likely to be a rapid increase in the number and size of cooperative sheep breeding groups in New Zealand as a supplement to objective recording and selective breeding within the smaller stud flocks. A greater degree of resource integration, reduction in overhead costs, encouragement of active farmer participation in applied breeding, and more flexibility to change selection objectives in line with changing market requirements should result.

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DISCUSSION

J. Eadie (Scotland). Could you give us a more realistic view of the beef performance figures. In a sense the figures presented were relative ones and we could say Friesian-Angus were about 30% better in productivity and efficiency. Thirty percent better than what?

Hight. Our Angus cattle usually wean calves at about 400 pounds. The Friesian straight-bred and crossbred would wean calves about 80 pounds heavier than that. Now we would expect the straight-bred Friesian to be about 100 pounds heavier than the Angus at weaning. The Friesian-Jersey crossbred or Friesian-Angus crossbred cow is of similar live weight to the Angus. When you express the weight of calf per unit of cow live weight, this results in a very marked increase in output per unit of cow live weight and taking the fertility and weight into account, this is the sort of conclusion we've got. Fertility of straight-bred Friesian cows 2 years old and older per number of calves weaned has been of the order of about 76% but the Friesian-Angus cross, for example, where 2-year-olds are included, the percentage of calves weaned per number of cows actually joined with the bull, has been about 95%. So our data strongly indicate that in terms of fertility, ease of calving and maternal ability, post-weaning growth rate of steer calves, onset of puberty in heifers, ease of calving and structural soundness, the Friesian crossbred animals have appeared to have an enormous amount to offer as a maternal beef dam crossed with a bull appropriate to the type of production system that you're aiming at. For example, if you're going to slaughter all your progeny, there's a possibility that a fast-growing lean meat type animal such as the Charolais would be very suitable. In New Zealand I would like to emphasize that our farmers usually go for a simple straight-bred system. There's still a lot of prejudice against the Friesian or Friesian crossbred animal in our beef industry.

L. Ainsworth (Ottawa, Canada). Could you tell me what attempts are being made to introduce the more highly prolific sheep breeds into New Zealand and what mating procedures do you use for breeding your sheep and cattle on the hill land?

Hight. Well, to answer the first part of your question, the research division does have a comprehensive breed evaluation program and this includes evaluation of exotic sheep. We recently introduced Finnish Landrace sheep into New Zealand in small numbers. They are not being released to the farming community until such time as we have evidence that they are completely free from disease, and, secondly, that the animals, the crossbred animals, and the type of crossbred is fairly clearly defined. So, we have a very great comprehensive program testing alterna-

tive breeds, crossbreeding systems with resources that we have and looking elsewhere for genetic material. We are particularly interested, of course, in the Finnish-Landrace because of its ability to increase fertility. Our present thinking is that a quarterbred Finn might be the most appropriate. But we're also interested in white-headed muttons and so on.

Ainsworth. The French have identified that the Finn has poor mothering ability. This is why they are not using it. They have gone to Russian Finn, the Romanov, and this apparently has far better mothering capabilities and certainly has the prolificacy of the Finn sheep. They're doing extensive evaluation programs for sheep at Bourgeset and some extensive studies on evaluation of breeds crossed to traditional French breeds, which might have useful information for you.

Hight. I think, though, we've got to be very careful that we evaluate the role of the exotics and where they fit and in what proportion we use them before we adopt widespread exploitation of these animals. The point that has been driven into us is that within their existing breeds there is an enormous variation in productive performance and quite a lot of that variation is inherited. If we have enough ingenuity to isolate those animals of high production, bringing them into a common environment so that we can compare them with each other, there is an enormous potential available for animal breeding. The large-scale group breeding schemes in New Zealand perhaps illustrate what can be done through farmer-to-farmer cooperation. It costs us—all costs in recording, computer costs, technical costs and so on—about $5 per ram produced in our large-scale breeding scheme and in that one scheme alone, in ram and bull costs, we saved a quarter of a million dollars a year over a population of 400 000 breeding ewes and 34 000 breeding cows all in the one setup. And there's no reason why these principles can't be applied to other countries appropriately adapted to the social and economic situation. The second part of your question concerned the mating procedures used. I'm not quite sure what you mean, but as far as sheep population goes, except in recorded populations where you obviously want sire and dam identification, most bull breeding herds would be single sire mated regardless of whether they were recorded or not, though the bulls may be rotated among mating groups with about 45 to 50 cows mated per bull in single sire groups. In the case of breeding ewes, these are usually mass-mated. Ram-to-ewe ratios vary enormously. An average figure would probably be 60 ewes per ram, but many farmers are extending this to 250 to 300 ewes per ram and the best I've heard is 500 ewes mated by one ram in a season where they mate to a group of ewes and then follow-up with yearling ewes which are mating later. The rams have an enormous capacity to mate sheep which we're not exploiting.

K. Inskeep (West Virginia, USA). I'd like to ask two questions about postpartum interval. First, with the Friesian crosses that you're using, do you have a longer postpartum interval? Second, many of the reports in this country would indicate that the prepartum feeding level is more important in determining postpartum interval than the postpartum feeding level with respect to energy. I'd like to hear your comments on that in relation to the statement you made about saving the best grass for the postpartum period.

Hight. In the first part of your question, we have found little trouble in getting the straight-bred Friesian to calve on schedule at 2 years of age under reasonable feeding systems. But under some drought conditions, the straight-bred Friesians have tended to have a delayed onset of estrus, post-calving in its second mating. As far as the Friesian crossbred animals, in this case the Friesian-Jersey, Friesian-Angus, and Friesian-Hereford cross, compared with the straight-bred beef breeds, we've had no problem in that at all in the 2-year-old, 3-year-old, or subsequent calvings and comparisons of mating behavior data, percentage of animals mated at different times, percent pregnant, etc. The crossbred animals have had a similar distribution pattern to our straight-bred beef breeds. I think it's very important to fit the management and feeding system to the genetic capability of the animal, which you and others emphasized yesterday. That seems to me to be critical.

The second part of your question was the feeding level interval from calving to first estrus. I feel that we've got a lot more work to do on this but in general I would agree with you that I think the successful onset of estrus post-calving, which is critical in setting up calving patterns in beef breeding herds, does require an integrated effort pre- and post-calving in levels of nutrition. I think that if you bring your cows down too far in condition at calving, that because their feed intake is limited and you've got a limited time from calving until you join them with the bull to get a concentrated mating, you must feed them well before and after calving, particularly after calving.

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Forage-Animal Production Systems on Hill Land in the Eastern United States

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Small farms, mechanization, operating costs, and hilly topography all have contributed to making many farming enterprises marginal in the northeastern United States. Many abandoned farms have been purchased by neighboring farmers to make profitable units. Other farms held for appreciation, without soil amendments, grazing, and occasional mowing, are reverting to objectionable species (Dore, 1936). It is increasingly more costly to restore such land to desirable grazing area.

Agricultural land is being diverted to urban, road, and industrial uses. In the future, ruminant agriculture on croplands may be replaced by crops for direct human consumption. Thus, hilly land in the northeastern U.S. can contribute substantially to the food supply through efficient forage-animal systems.

Historically, forage from the soil-climate complex in the humid Northeast has nourished horses and ruminants. No serious toxicity problems exist; selenium deficiency is a problem in some areas, and grass tetany is common. Except for the short grazing season in the more northern latitudes, operation costs can be reduced by simple forage-animal management systems as discussed herein.

FACTORS IN DEVELOPING AND MANAGING FORAGE ANIMAL SYSTEMS IN THE NORTHEAST

Perennial Forages

1. *Shifting a forest climax to perennial forages.* There is rather good rainfall distribution (818 to 1049 mm), and mean annual temperatures range from 6.9 C to 13.3 C in the Northeast. Temperatures are milder and rainfall higher in adjacent Mid-Atlantic states. The effects of the climate plus forest climax vegetation modified by parent materials have led to the development of soils that are mildly to strongly acid, low in organic matter and fertility, and structured so as to inhibit development of deep roots because of poor aeration and fertility (Jenny, 1941).

The nutrient and pH requirements for perennial forages are higher than for forest species; hence, soil amendments for forages are essential. Soil N and other nutrients restrict growth and maintenance of grasses (Kennedy, 1958; Marriott, 1961; Robinson and Sprague, 1947; Wagner, 1954). Lime, phosphorus, and potassium must be applied to deficient soils for economical yields, N being supplied by legumes in perennial mixtures such as bluegrass-white clover (*Poa pratensis* L.-*Trifolium repens* L.), orchardgrass-ladino clover (*Dactylis glomerata* L.-*T. repens* L.), timothy-red clover (*Phleum pratense* L.-*T. pratense* L.), and bluegrass-birdsfoot trefoil (*P. pratensis* L.—*Lotus corniculatus* L.). N fertilizer sped up regeneration of forage grasses but deterred legumes (Beaumont, 1932; Brown *et al.*, 1960; Brown and Munsell, 1941; Carrier and Oakley, 1914; Hutcheson, 1941; Nowosad, 1933; Odland, 1930; Pohlman and Cornell, Jr., 1943; Robinson and Price, 1938; Schaller and Pohlman, 1955; Smith *et al.*, 1950; Sprague *et al.*, 1947).

Undesirable vegetation on potentially productive soils in favorable environments may be improved by: (1) applying soil amendments without reseeding (Brown and Munsell, 1956; Brown *et al.*, 1960; Pohlman and Cornell, Jr., 1943; Smith *et al.*, 1950); (2) plowing or other seedbed preparation with reseeding and soil amendments; (3) partially destroying unproductive vegetation mechanically or with herbicides and applying seed and soil amendments (Graber, 1927; Harrington and Washko, 1962; Smith *et al.*, 1950; Sprague, 1960; Sprague, 1952; Sprague *et al.*, 1947.); and (4) establishing legumes without destroying sods by applying needed soil amendments and reseeding legumes with various methods such as: (a) grazing closely and surface seeding or drilling (Blaser *et al.*, 1969; Templeton *et al.*, 1970; Wolf, unpublished data), or, (b) seeding in bands by reducing competition by tillage or herbicides (Taylor and Templeton, 1976; Van Keuren and Triplett, 1970). Sprague *et al.*, 1952, found that it required three years for topdressed pasture to produce yields similar to complete renovation. Reseeding of white or ladino clovers yearly without soil preparation gave good stands (Blaser *et al.*, 1969; Templeton *et al.*, 1970). During 25 years of good management of continuously grazed bluegrass-white clover pastures, white clover has persisted via perennial plants and natural reseeding (Blaser *et al.*, 1969).

2. *Nutritional value and yield of perennial forages adapted to hill lands.* With controlled leafiness and availability, live weight gains/head and/ha of bluegrass-white clover pastures are similar to other grass-legume mixtures (Table 1) (Blaser *et al.*, 1969; Bryant *et al.*, 1961; Burns *et al.*, 1970; Ronningen *et al.*, 1955; Templeton *et al.*, 1970). Live weight

TABLE 1. Potential animal performance and production per ha for pasture mixtures for hill lands as shown by Maryland and Virginia data*

Pasture	Grazing days/ha VA	Average Daily Gains, kg/steer VA	Live Weight Gains kg/ha VA	MD
Orchardgrass-ladino clover				
No N	289	0.56	369	410
Orchardgrass—with N	349	0.49	374	
Ky 31 fescue-ladino clover				
No N	340	0.46	347	378
KY 31 fescue—with N	452	0.41	412	
Bluegrass-white clover				
No N	290	0.55	350	392

*Blaser *et al.*, 1969; Ronningen *et al.*, 1955.

gains for bluegrass-white clover pasture in Maryland and Virginia were 350 and 392 kg/ha, respectively, similar to gains from orchardgrass or Kentucky 31 tall fescue (*Festuca arundinacea* Schreb.), each with ladino clover. Live weight gains/head for tall fescue-ladino clover were lower than for mixtures in Virginia. In Kentucky, live weight gains/head grazing bluegrass-ladino clover and bluegrass-alfalfa were indentical (0.56 kg/day); live weight gains for the two mixtures were 382 and 602 kg/ha, respectively. However, the alfalfa-bluegrass was fertilized at higher rates. During six years in Virginia, gains/head tended to be higher for continuously grazed bluegrass-white clover than for grazing several legume mixtures in rotation. In the Appalachian region of North Carolina, when grazing bluegrass-white clover with some orchardgrass, gains were 0.58 kg/head/day and 192 kg/ha/year. Supplemental grazing with alfalfa or birdsfoot trefoil or seeding birdsfoot trefoil in bluegrass-white clover pasture did not generally improve gains/head or /ha. Dairy cows grazing alfalfa-orchardgrass or bluegrass-white clover-birdsfoot trefoil gave similar amounts of milk, but milk yields/ha were highest with alfalfa.

When grazing various temperate forage grasses with similar leafiness, grazing pressure, and leguminous components, similar animal performance occurs, except for tall fescue. Tall fescue usually depresses animal performance because of low intake, and its broad adaptation and aggressiveness depresses legumes (Blaser *et al.*, 1969; Blaser *et al.*, 1976).

About 1930 to mid-1945, a concept developed that bluegrass was an undesirable, unproductive, summer-dormant, low-quality grass. Thus, in experiments in many states, it was eradicated by fire, herbicides, plowing, discing, and seeded to other species such as orchardgrass, timothy, ladino clover, red clover, and alfalfa. This unfortunate concept became prominent because the yields of unfertilized, weedy, clover-free bluegrass were compared to liberally fertilized seeded species, giving inflated yield advantages over bluegrass pastures. Also, the mowing techniques suited for taller growing forages underestimated the yield for bluegrass-clover mixtures (Blaser *et al.*, 1969; Ronningen *et al.*, 1955).

Yield potentials of perennials are often confounded with soil characteristics and utilization methods; e.g., alfalfa or red clover harvested for hay on fertile, well-drained soils produce more than bluegrass-white clover; whereas, on shallow, fertile soils for pasture, yields may be similar or best for white clover-bluegrass. Bluegrass-legume mixtures have excellent potentials on hilly lands in the Northeast; they are persistent, responsive to management, widely adapted, suitable for flexible management, and of quality equal to other temperate species. It is common knowledge that productive bluegrass-white clover mixtures with fair management have persisted in the Appalachian region for over 100 years without reseeding. Bluegrass-white clover mixtures during favorable seasons without N produced 7 840 kg/ha, as compared to 9 500 kg/ha with N plus irrigation (Robinson and Sprague, 1947).

Growing legumes with grass associations improves animal performance, as compared with N-fertilized grasses, and generally reduces costs of producing forages (Table 1) (Blaser *et al.*, 1969; Burns *et al.*, 1970; Davis and Klosterman, 1959; Van Keuren and Heinemann, 1958). Higher animal outputs from legume-grass than from grasses is attributed to more rapid digestion of the legumes, thereby augmenting intake (Thornton and Minson, 1973).

3. *Forage growth curve, digestibility, and animal performance.* The growth curve for bluegrass-white clover pastures, obtained with variable stocking to maintain a near constant grazing pressure (head/available forage), shows a carrying capacity of over six head/ha during spring and around two head during summer (Fig. 1). Low summer yields are associated with moisture stress and reductions in photosynthesis (Sprague *et al.*, 1947, and Wolf, unpub. data). Although all temperate species have similar growth curves, deeper rooted species such as red clover and alfalfa produce more in summer than bluegrass-white clover (Blaser *et al.*, 1969; Sprague *et al.*, 1952). Bluegrass with clover gives higher yields than orchardgrass during autumn. Tall fescue with early spring and late autumn growth with erect leaves that stay green most of the winter is desirable for winter grazing. August N-fertilized canopies accumulate up to 4 400 kg/ha of forage dry matter (Taylor and Templeton, 1976; Van Keuren and Triplett, 1970).

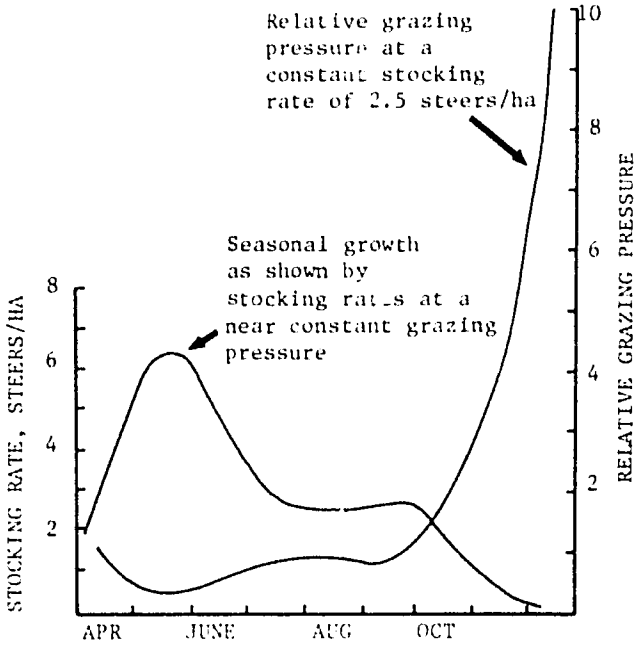

Figure 1. Seasonal stocking rates at a near constant grazing pressure with bluegrass-white clover pastures and relative grazing pressures at a near constant stocking rate of 2.5, 318 kg steers per ha. Constant light stocking, commonly used by farmers, wastes the spring forage highest in digestibility when milk or meat output is highest per head (Fig. 3, Blaser *et al.*, 1969).

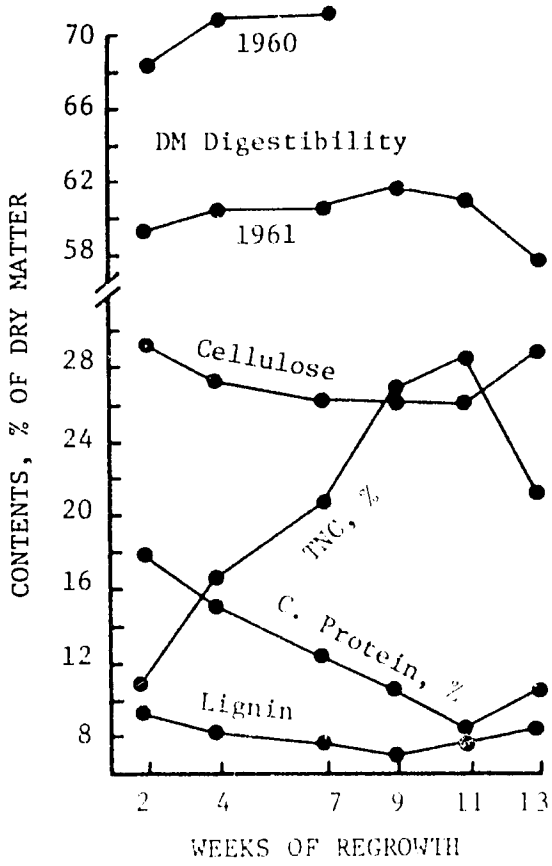

Figure 2. Kentucky 31 fescue was cut and accumulated after September 2, 1960, and after August 14, 1961. Higher *in vivo* digestibilities for 1960 than for 1961 may be attributed to cooler temperatures while top growth accumulated. Chemical constituents are shown for 1961 only. (Brown *et. al.*, 1963.)

Forage intake and digestibility shifts with season due to soil, climatic, and biotic interplaying factors (Blaser *et al.*, 1976). For example, physiological reactions within a plant possess different optimum temperatures; photosynthesis occurs at lower optima than dry matter production (Brown and Blaser, 1965). Thus, as canopies of a cold-tolerant species such as tall fescue accumulate during the cool autumn season, cellulose and lignin percentages decline because non-structural carbohydrates (TNC) accumulate rapidly (Fig. 2). Near complete digestibility of TNC causes accumulated canopies to maintain high digestibilities. For summer growths during high temperatures, the high rates of respiration compiled with low rates of photosynthesis cause low TNC and high cellulose and lignin percentages (Blaser *et al.*, 1976, and Wolf, unpub. data).

Thus, for a given forage, morphology (stage of growth) and grazing pressure, the output per ruminant varies with season (Fig. 3). The shifting daily live weight gains from high to low to medium for spring, summer, and fall, respectively, occurred with each of three stocking rates for bluegrass-white clover pastures. There was much ungrazed forage with light stocking (Fig. 3). Spring gains were not inflated as the heifers were wintered to gain about 0.4 kg daily. Also, all three stocking rates were 50% higher in spring than for the other seasons. Seasonal live weight gains appear allied with digestibility, values being 73.0, 54.6, and 58.7% for early spring, August, and September, respectively. The changing percentages of TNC, lignin, and cellulose in forage may influence animal performance. In another bluegrass grazing experiment, steers in a thin condition gained 0.92 and 1.14 kg daily during 84 days of spring grazing when stocked at 2.5 and 1.25 steers/ha (Fig. 4). Summer gains declined with low stocking and were very low with high stocking.

During normal spring seasons, about two-thirds of the year's growth is produced during the first third of the season (Hein and Cook, 1934). With constant and light stocking to assure an adequate supply of forage during summer, as practiced by many farmers, an estimated half of the best quality spring forage is wasted. Some principles to apply to ruminant-forage management systems are: (1) shifting dry lot fed dairy cows to high quality flush spring pasture would be good management on some farms; (2) fall calving with July weaning would furnish the most and best pasturage when calves

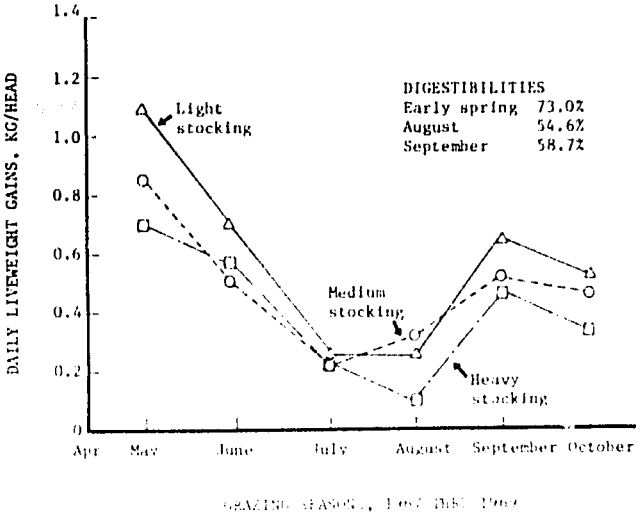

Figure 3. Daily live weight gains of heifers during the season for three stocking rates—light, 4 yearling heifers/1.22 ha; medium, 4 heifers/0.81 ha; and heavy, 4 heifers/0.61 ha—grazing bluegrass-white clover pasture (Johnson, 1970) and digestibilities of bluegrass at three seasonal dates (Reid *et al.*, 1964). Stocking rates above were for the spring season—about 100 days—thereafter, there was a 50% reduction in stocking rate. Light stocking left much excess forage.

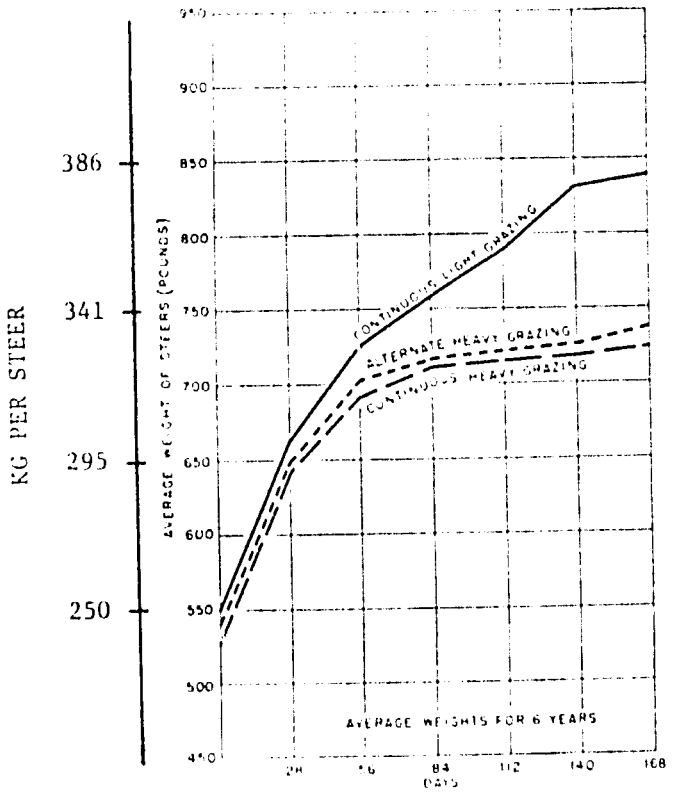

Figure 4. Average weights of steers at 28-day intervals during six years (1929-1934). Light grazing was at the rate of 1.25 steers/ha, and heavy grazing was at the rate of 2.5 yearling steers/ha. (Hein and Cook, 1934.)

need more energy; (3) stockers and dairy replacements might be stocked at a double rate to utilize the spring growth; (4) lambing could be dated so lambs utilize spring growth; (5) cattle finished for slaughter would obtain the highest digestible intake during the spring season; energy supplements during summer would be liberal.

4. *Stage of growth, grazing pressure (nutrition), and utilization methods.* Details on managing forages for persistence, botanical balance, high yields, and quality with grazing pressures and methods of utilization as related to animal performance appear elsewhere (Blaser *et al.*, 1974; Blaser *et al.*, 1976; Blaser *et al.*, 1973); hence, this discussion of animal-forage systems is brief.

As perennial forages shift from leafy to stemmy growths, yields increase, but animal performance declines and may become negative because of low digestibility and intake (Blaser *et al.*, 1976; Kennedy, 1950; Smith, 1973). Because hay and silage crops are cut in advanced stages of growth and encounter fermentation and leaf losses, animal performance is better with judicious grazing of leafy pastures than with silage or hay feeding (Blaser *et al.*, 1969; Blaser *et al.*, 1976; Minson *et al.*, 1960; Reid, 1959; Van Soest, 1965).

As grazing pressures (animals/forage unit) increase, the output per head declines and even becomes negative (Mott, 1960). Digestible intake declines with grazing pressures. Increasing stocking rates (ruminants/ha) are often allied with grazing pressures but are not good indices for predicting animal performance over a range of environments because of the variability in forage productivity of species with naturally varying soil, climatic, and biotic factors.

The output/head can be best with any grazing method, depending on the grazing pressure, canopy management, growth stage, and ruminant control and technique (Blaser *et al.*, 1974; Blaser *et al.*, 1973). When good utilization (heavy grazing pressure) is practiced with rotational grazing, the limited selective grazing gives lower animal outputs for rotational than for continuous grazing. During rotational grazing within a fresh pasture, the shift from an abundant canopy to a sod residue as cattle consume the forage simulates a shift from a low to a high grazing pressure and a high to a low nutritional intake as forage is utilized in a pasture. This is verified by undulations in animal performance. With continuous grazing, there must be some excess forage, thus a tendancy for lighter grazing pressure, more selective grazing and a more even and slightly better nutrition for continuous than for rotational grazing. With controlled grazing pressures, growth stage, and botanical composition, outputs per animal for rotational and continuous grazing are similar. Thus, continuous grazing of many species such as

bluegrass-white clover, orchardgrass, or tall fescue with ladino clover common in the hilly land in the Northeast provides animal performance comparable to rotational grazing. However, somewhat higher outputs/ha occur for rotational than continuous grazing at high stocking rates. Judicious rotational grazing with tall species such as alfalfa gives sharply higher animal outputs/ha than continuous grazing. Rotational grazing is most useful when made a part of forage-animal management systems.

High outputs/animal with low grazing pressures cause wasted forage, low outputs/ha, and declines in forage growth and quality because of loss of clovers, weed encroachment, and low recycling of animal excreta (Blaser *et al.*, 1974; Johnson, 1970; Mott, 1973; Sears, 1950).

TABLE 2. Daily live weight gains of steers and milk production per cow as influenced by two animal groups (first and last grazers) and ordinary whole canopy rotational grazing*

Pasture Mixtures (N kg/ha)	Rotational Grazing Two Animal Groups: First Grazers	Rotational Grazing Two Animal Groups: Last Grazers	Ordinary Rotational Grazing, 1 Animal Group
		kg	
	Steers		
Orchardgrass-N 224	0.56	0.36	0.44
Tall fescue-N 224	0.50	0.34	0.40
Orchardgrass-ladino clover	0.70	0.52	0.60
Tall fescue-ladino clover	0.60	0.35	0.54
Bluegrass-white clover	0.68	0.45	0.59
Average 1958 and 1959	0.61	0.40	0.51
	Milk Cows, 1957		
Orchardgrass-ladino clover	19.50	13.86	—
Orchardgrass-alfalfa	14.72	9.90	—

*Blaser *et al.*, 1969.

High outputs/ha and /head are obtainable by using two groups of animals—"first and last" grazers—in a rotational grazing plan. The first grazers, with low grazing pressure and high nutritional intake, augment output/head sharply as compared with last grazers which simulate a high grazing pressure with low nutrition (Tables 2 and 3). These grazing pressure concepts should be related to supplying the nutritional needs of ruminants in forage-animal systems.

5. *Supplying nutritional needs of ruminants with perennial forages.* Perennial grass-legume mixtures, when leafy and grazed at the appropriate grazing pressure, generally supply all dietary needs, except salt and certain mineral supplements of cow herds, sheep flocks, stocker cattle, replacements, and finished slaughter cattle with special animal-forage management; lactating cows and short finishing of cattle and lambs also require energy supplements (N.R.C. 1970; Wise *et al.*, 1967).

The nutritional requirements and economic returns from liberal feeding differ for classes of ruminants and for production cycles. For example, beef cows tolerate variable low-to-medium nutrition and do not give additional returns for high and costly nutrition; however, continuous high nutrition is necessary and economic for calves. For example, after calves were 4 months old, cows were fed at low and high nutrition for daily live weight gains of −0.54 and +0.23 kg. The nutrition of cows did not influence the gains of their creep fed calves, which averaged about 0.91 kg daily. However, 4-month-old calves restricted to milk from liberally fed dams gained only 0.15 kg daily. In a 45-day experiment, 4-month-old calves with their dams on pasture gained 0.82 kg daily. Other calves, nursing in dry lot twice daily on cows grazing the same pastures, lost 0.04 kg daily (Blaser *et al.*, 1974; Hammes *et al.*, 1959). Also, 8-week-old Jersey calves weighing 55 kg digest high quality grasses as efficiently as cows (McArthur, 1957).

To minimize feed costs, needed nutrition must be timed with cycle of production. Good nutrition for cows begins a few weeks before calving until calves are 3 or 4 months old. This coincides with calving, producing milk for young non-ruminating calves, and early estrus and conception. Thereafter, restricted hay feeding or high grazing pressures below maintenance are practical. Cows losing 80 to 100 kg yearly in 5 successive cycles during 4 months to a few weeks before calving regained weight rapidly on good pasture and did not adversely influence conception or birth and weaning weights of calves.

Animals and forages should be managed concurrently in systems to furnish the nutritional requirements as follows: (1) excellent for calves and lambs, (2) variable medium to low for ewes and beef cows, (3) medium to excellent for replacement heifers and stockers, (4) excellent for finishing cattle, and (5) super excellent for high-producing lactating cows.

High and low grazing pressures cause low and high nutrition with palatable grass-legume mixtures (tall fescue excluded). Light grazing pressures with continuous grazing, first grazers in rotational grazing, or creep grazing give the best possible nutrition from perennial forages. Grazing pressure is the key for rationing the needed nutrition for classes of ruminants and for compromising production/head and /ha wisely. Low nutrition with high grazing pressures (close grazing) causes low production/head as selective grazing and intake are restricted. However, such forage is of good enough

TABLE 3. General and relative associations among parameters for a given pasture-animal complex at various grazing pressures[a]

Stocking[b] Rates	Grazing Pressures	Herbage per Head	Selective Grazing	Ungrazed Wasted Herbage	Nutritional Status per Head[c]	Yield of Animal Products Per Head	Yield of Animal Products Per Hectare	Potential Pasture Yield
Continuous Grazing								
Low	Low	High	High	High	High	High	Low	Low
Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High
High	High	Low	Low	Low	Low	Low	Medium	High (——)
Rotational grazing—High to Low Nutrition While Grazing a Lot								
Starting Grazing in a Fresh Pasture (as with First Grazers)								
Medium	Low	High	High	High	High	High	V. High	——
Finishing Grazing in a Rotated Pasture (as with Last Grazers)								
Medium	High	Low	Low	Low	Low	Low	V. low	——
Mean values	Medium	Medium	Medium	Medium	Medium	Medium	High	High

[a]Blaser *et al.*, 1974.
[b]Stocking rates are not necessarily allied with grazing pressures, and constant stocking rates cause sharp changes in grazing pressure (Fig. 6).
[c]Intake of digestible energy and protein and minerals.

nutritional quality to maintain animal health at sub-maintenance levels.

Low grazing pressures to obtain high animal performance sacrifice output/ha since much forage is wasted. Thus, using ruminants that require high nutritional intake as first grazers and others that require low nutrition as second grazers avoids wasted forage and maximizes returns/ha. Examples of first and last grazing practices which ration nutritional intake are: (1) finishing steers as first grazers and beef cows as second grazers (calves could creep graze with steers); (2) finishing steers first and stockers last; (3) high producing lactating milk cows first, dry cows second; and (4) creep grazing calves while cows encounter heavy grazing pressures. Such managements can be simple, requiring only a few fields (see Forage Animal Systems).

Animal Performance with Annual and Perennial Forages

The more level fields suitable for mechanization may be used for high energy silages (grain cultivars of corn and sorghum harvested when nearly mature) for finishing steers, wintering young stock, and feeding lactating cows. Erosion problems can be minimized on rolling topographies by sod seeding or double cropping small grains with corn or sorghum.

Approximate live weight gains attained on various harvested forages and on pastures are given in Table 4 for yearling cattle in good condition that had gained

TABLE 4. Cattle gains from forages at the Virginia Forage Research Station, Middleburg

Forage	Approximate Average Daily Gains (kg) Sup. a[a]	Sup. b[b]
Corn—50% grain hard dent stage, 38–42% dry matter	1.05	1.23
Short grain sorghums—hard dough stage	0.91	1.05
Medium height grain sorghums—hard dough stage	0.82	1.00
Alfalfa-orchardgrass—wilted	0.36	0.59
Wheat—hard dough stage	0.68	0.91
Barley—hard dough stage	0.59	0.86
Rye—50% headed, wilted	0.36	0.91
Forage sorghum—male sterile	0.23	0.73
Corn silage & alfalfa-orchardgrass silage—3:1 ratio	1.00	1.14
Alfalfa-orchardgrass—direct cut	0.01	0.77
Alfalfa hay	0.36	0.77
Pasture—heavy grazing pressure	0.41[c]	——
Pasture—medium grazing pressure	0.64[c]	——
Pasture—light grazing pressure	0.73[c]	——

[a]Sup. a—Protein supplements for grass silages.
[b]Sup. b—Protein and/or corn grain equal to 1% of body weight.
[c]No supplements.

around 0.34 kg daily. Using 2-year-old steers under maintenance or sub-maintenance rations before evaluating forages would inflate gains as much as 50% (Hunt, 1917; Kincaid *et al.*, 1958). Steers consistently gained more than a kg daily, reaching choice carcass grades when fed corn silage supplemented with urea or a 50/50 urea/protein meal mixture based on N content and minerals. Small grain silages were of medium quality, rye being poorest. High energy silages (corn and grain sorghums) need not be supplemented with grain for finishing mature cattle. Alfalfa-orchardgrass mixtures fed as silage or hay gave animal performances inferior to corn silage, as well as some small grain silages and pasture, except at high grazing pressures.

FORAGE-ANIMAL SYSTEMS

In grazing regimes, animals and plants both must be considered concurrently. Two inseparable concepts are: (1) manage ruminants to "fit" and utilize the seasonal quality and quantity of forages (Fig. 1 and 3) to obtain nutritional needs of various ruminants for cycles of production and (2) manage soils and plants for species longevity, balance of components, potentially high yields and quality, and good forage distribution. Farm units must be economical and production/animal and /ha wisely compromised. Systems of management vary with soils and topography, class of ruminants, facilities, and operating knowledge and should be as intensive as possible but with low labor, machinery, and other inputs.

Systems for Steep Land Areas

1. *Cow-Calf Herds.* Steep topographies with little or no land for tillage and with various perennial grass-legume mixtures are suited for cow herds or ewe flocks, stockers, replacements, or for finishing cattle for slaughter (priorities are in the order listed). Fig. 1 shows that constant stocking rates cause extremes in grazing pressure because of flush spring and slow summer growths. Some operating principles are: (1) utilize the flush spring growth of highest quality by doubling the stocking rates; (2) harvest the fields not used for spring grazing for winter feed; (3) graze more pasture area as needed during summer and fall; (4) accumulate some mixtures, especially tall fescue with red clover, beginning in early August for winter grazing; (5) graze all mixtures until early summer, when pasture is inadequate, to reduce grazing pressure and replace hand feeding; (6) shelter for hay and cattle is not usually needed; (7) manage cattle to recycle animal excreta evenly. The latter can increase productivity by 25% or reduce fertilization costs (Sears, 1950). Shelter and shade cause animals to bunch excreta and augment pollution; and (8) use ruminants, especially beef cows, to replace machines, fossil fuel, and labor: e.g., (a) with heavy spring stocking, animals eat young weeds and encourage clover, thereby making mowing unnecessary (Carrier and Oakley, 1914; Johnson, 1970); (b) heavy continuous grazing during fall to spring regenerates surface-seeded legumes as sparse, short sods reduce competition for legume establishment making machine renovation and chemicals unnecessary.

Simple forage systems with these principles and low cost inputs for raising calves efficiently are exemplified by preliminary results from a Virginia experiment. Each three field system has two fields primarily for winter feed and 55% of the area in one field is pasture. Of three forage systems (Table 5), a common system (a) of hay for winter feeding on bluegrass-white clover pasture is compared with (b) bluegrass pasture with stockpiled Kentucky 31 tall fescue-red clover and (c) fescue-ladino clover pasture with stockpiled fescue-red clover. Pastures are grazed from April to fall. The fescue-red clover fields are hayed once, summer grazed, and then stockpiled accumulating around 4000 kg of dry matter/ha from early August onward and rationed for grazing during November–May. Hay in systems b and c is stacked in fields with a buck-rake stacker for self feeding, if needed, or for use during snow cover. Some hay for these systems has also been baled and stored or round baled for *in situ* grazing. During the late winter–spring season, the entire area is grazed to replace hay feeding. Late spring grazing delays the fescue-red clover harvesting, but this facilitates hay curing in June. Spring and fall calves obtain all their feed from the systems. With some b and c systems, hay feeding has not been necessary for three years. Alfalfa-orchardgrass is usually cut and baled for hay twice yearly and grazed, creep grazed, and late autumn grazed.

Simple wood panels with open apertures between all three fields in each system serve for creep grazing when cows encounter heavy grazing pressures. For example, fall-born calves encountering heavy grazing pressures in spring creep graze one alfalfa-orchardgrass or one fescue-red clover sward in the respective system, even as the first hay crop develops. Staggering hay cutting provides young growth for creep grazing.

Creep grazing encourages heavy stocking with cows, high weaning weights of calves, and high production/ha, as calves do not encounter heavy grazing pressures and stunted growth. When grazing pressures are high, calves readily "crawl" through the creep gaps, leaving their mothers to graze selectively, even at far ends of the field. Calves respond to creep grazing only when there is a heavy grazing pressure; low grazing pressures or changing and complicated managements explain the negative results often obtained with it. If energy supplements

TABLE 5. The performance of beef cows and calves as influenced by forage systems, calving season, and stocking rate (average values during two years, Virginia Forage Research Station)[a]

Forage Systems		Calf Data			Seasonal Live Weights of Dams (kg)			
Pasture	Winter Feed or Pasture	Stocking Rate, ha/ Cow & Calf	Gain/ Day (kg)	Weaning Weights[b] (kg)	Dec.	Apr.	July	Dec.
	A. Systems with Spring (February–March) Calving							
a. Bluegr-white cl	Alfalfa-orchardgr	0.65	0.95	238	553	478	505	552
b. Bluegr-white cl	Fes-red clover	0.65	0.94	244	524	437	484	510
c. Fes-ladino cl	Fes-red clover	0.65	0.86	210	504	445	455	506
	B. Systems with Autumn (September–December) Calving							
a. Bluegr-white cl	Alfalfa-orchardgr	0.65	0.81	235	506	449	485	528
b. Bluegr-white cl	Fes-red clover	0.65	0.89	236	515	471	494	531
c. Fes-ladino cl	Fes-red clover	0.65	0.78	215	504	424	473	522
	C. Systems with Stocking Rates Compared, Spring Calving							
b. Bluegr-white cl	Fes-red clover	0.65	0.94	244	524	437	484	510
b. Bluegr-white cl	Fes-red clover	0.81	0.96	235	502	535	474	516
	D. Systems with Stocking Rates Compared, Fall Calving							
a. Bluegr-white cl	Alfalfa-orchardgr	0.65	0.81	235	506	449	485	528
a. Bluegr-white cl	Alfalfa-orchardgr	0.81	0.89	246	518	446	487	537

[a]The cows were restricted to the systems all year without shelters.
Forage system a: Cows were fed hay once daily (5 kg TDN until calves were 4 months old and 3.2 kg thereafter). Calves had ad lib feeding of orchardgrass-alfalfa hay.
Forage systems b and c: Cows and calves grazed the stockpiled Kentucky 31 fescue-red clover mixture during winter.
Creep grazing was practiced all year whenever grazing pressures with cows were high to provide needed nutrition for calves.
[b]Spring calves weaned October 30 and autumn calves weaned June 30.

are inexpensive, creep feeding may be substituted for creep grazing.

Results for two years with the three forage systems with two calvings show sharp weight changes of cows, but these have not influenced calving and weaning weights adversely. However, system c (fescue with legumes all year) is not recommended since calves on system c have lower weaning weights than for other systems. Similar cow and calf performances with stocking rates are attributed to rationing the forage to cows while maintaining high nutrition for calves with creep grazing.

With bluegrass pasture, a simple system is to restrict cow herds to the steepest pasture by double stocking during spring. The ungrazed area on less hilly land hayed in June and grazed immediately after hay is removed adds 50% more land for later grazing. Mowed bluegrass residues are leafy after haying. Yields of the hayed portions of bluegrass could be improved by introducing taller growing legumes (red or ladino clovers or birdsfoot trefoil). Creep grazing could be embodied into this simple system.

2. *Stockers, Replacements, and Finishing.* Stockers and replacements: Systems proposed for beef herds with lighter grazing pressures would be suitable. Forages should be high in legumes, and low energy supplements may be necessary with stockpiled tall fescue. Another system is double stocking during the spring–July season and selling the heaviest cattle to feeders to reduce the grazing pressure during the summer–fall season.

Finishing for slaughter: Yearling cattle grazing perennial forages do not usually make satisfactory liveweight gains for suitable carcasses because of inadequate energy ingestion (Black *et al.*, 1940; Blaser *et al.*, 1976; Hein and Cook, 1934; Heinemann and Van Keuren, 1958; McClaugherty *et al.*, 1975; Wise *et al.*, 1967). Steers wintered to gain about 0.5 kg daily gained about .55 kg daily on pasture and over 1 kg daily when supplemented with a self-fed fat-corn or salt-corn mixture to limit intake to 1% of bodyweight (McClaugherty *et al.*, 1975; Wise *et al.*, 1967). When grazing bluegrass-white clover in West Virginia for 140 days with 2-year-old steers, apparently in thin condition, the daily gains

were 0.8 kg for pasture alone, 1 kg with energy supplements during the last 70 days, and 1.1 kg/head with energy supplements all season. Economically, it was best to supplement energy for the last 70 days of grazing.

Yearling steers grazing bluegrass-white clover pastures in the Appalachian region gained 0.8 kg daily during the first 70 days and 0.56 kg for the season (McClaugherty *et al.*, 1975). With energy supplements during the last 105 days and for the entire season, the steers gained 1 kg and 1.1 kg/day, respectively. Heifers with energy supplements gained 1.1 kg daily during the spring-summer season, making good carcass grades. Stocking rates were 50% higher in spring than for the rest of the season to achieve better forage utilization.

The data suggest forage-animal finishing systems for hilly pasture land as follows: (1) Stock at constant high rates for the entire grazing season, supplementing energy by early summer when yield and quality decline. (2) Stock two separate pastures heavily with steers or with heifers fed energy supplements, selling heifers for July slaughter; next supplement steers grazing both pastures for October slaughter. (3) Restrict steers to 50% of grazing area during spring, harvesting the ungrazed area for hay. Lighten grazing pressures during summer by grazing the entire area and supplementing energy. (4) Use steers as first grazers all season without energy supplements and cows as last grazers. Calves may creep graze with steers. (5) Steers and ewe-lamb flocks could continuously graze together during the spring until the fat lambs are sold. Steers then could be shifted to first and ewes to last grazers. (6) Steers or heifers could be managed as first grazers; replacements or stockers as second grazers.

Systems With Crop and Hill Land

Crop land in hilly areas is ideal feed for finishing yearling cattle for slaughter and dairying. Continuous cropping with corn, when erosion is not a problem, or corn-alfalfa rotations provides high yields of quality forage with nearly balanced rations for dairy cows and ruminants to be finished. Potential live weight gains range from 1700 to 5300 kg/ha for the best cultivars of corn silage supplemented with protein and minerals. It is generally not practical to substitute sudan-sorghum forages for corn or grain sorghum silages; the latter produce higher yields, and better quality and reduce harvesting costs.

Systems With Milk Cows

1. Manage lactating cows as first grazers, to consume about 50% of the flush high-quality pasture during the spring-summer season, shifting to corn silage-alfalfa dry lot feeding when pasture growth is inadequate. Dry cows and replacements serve as last grazers until lactating cows are shifted to dry lot. Thereafter, graze the entire pasture area rotationally or continuously, depending on species.

2. Use lactating cows as first grazers all season, beginning with bluegrass, and then graze regrowths of other grass-legume mixtures that have been harvested once or several times for winter feed. Grazing more land as the season advances promotes high nutrition by maintaining low grazing pressures. Dry cows and replacements serve as last grazers.

3. Dry lot feed lactating cows all year when most of the land can be cropped intensively with corn silage and alfalfa; e.g., maintaining tilth and fertility and controlling erosion.

Systems With Beef Cattle

It is generally most profitable to use rations high in corn silage for weanlings, suckling calves, early weaned calves, or for short finish feeding for slaughter. Stockers from perennial forage-animal systems mentioned earlier respond to finish feeding for slaughter when fed corn or grain sorghum silages supplemented with protein and minerals.

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DISCUSSION

Unidentified. How did you establish your initial stocking rate that you selected?

Blaser. Bob Van Keuren came to VPI. He said we could get by with an acre-and-a-half. We were talking in terms of acres. Pat said, "You can't do it." We compromised and we used one, two, and three acres. The stocking rate at .68 ha/animal unit is too low, but nothing's being wasted. We harvest one crop of hay from the red clover, the alfalfa is harvested one to three times, and we're keeping a budget of the excess feed from these systems so we can calculate what we need. We just made a good guess to be perfectly frank. Incidentally, these are more than twice the stocking rates used in the beef cattle industry in Virginia.

T. R. Terry (Kentucky, USA). Your farmers obviously, in this case, use woven wire, but creep grazing calls for some good fencing. Can you do it with barbed wire?

Blaser. Yes, I think you can do this with barbed wire.

Terry. The other question is, where you cut one crop of red clover were you able to maintain stands in the red clover longer than the two years ordinarily?

Blaser. You know we cut red clover to simulate grazing for several years now. Incidentally, this idea came to us from one of our graduate students—he cut red clover in August, September, October, November, and it lived over beautifully. So now we're thinking on alfalfa. In the spring there's a little shortage of feed, and Dr. Dale Wolfe is working on the scheme of grazing alfalfa continuously in the spring season till bluegrass pasture comes along. This is the way to lighten the grazing pressure. You don't have to feed hay, and this is why with some of these systems we've gone through three successive winters without feeding a bite of grain. The plants are more plastic than we think, and we're looking into this matter right now of harvest handling these taller-growing plants in a way so that there's less mechanization and also to help provide nutritional needs. When alfalfa is growing very slowly or red clover is growing slowly in the autumn, you can't pull the food reserves down because respiration is low, that is cell division, and expansion is low. Photosynthesis is very efficient because these are photorespiring plants and they're more efficient at cool temperatures than at hot ones, and so we're getting by.

K. F. O'Connor (New Zealand). Thanks for trying to put this analysis in terms of grazing pressure because I think this is the really fruitful approach. Let me remind people here, by way of comment first of all, that McMeekan never called his system rotational grazing versus set stock.

Blaser. Those that reviewed his work did.

O'Connor. McMeekan described the systems that he was comparing as controlled heavy stocking versus uncontrolled heavy stocking and controlled light stocking versus uncontrolled light stocking. Now, I don't think it's quite fair to say it was a put and take one—that the number of stock in the system stayed the same. But he took out areas for conservation of forage. That was the "take" if you like, whereas put and take generally means adding animals into the system. McMeekan in 1952 said something very clearly which I believe we continually forget. He said: pasture supply is basically seasonal and highly inelastic; animal needs are highly elastic and manageable. The lesson that Graham Hight was giving us earlier was the application of fitting the animal needs curve to the pasture supply curve. In the way that you've expressed it, Roy, you've simply put your steer needs curve against your pasture supply curve and it looks a very difficult kind of fit, but of course your steer needs curve is only part of your total needs curve. Now, the most important single factor, as McMeekan pointed out, in controlling your needs curve was your date of calving. You're in a situation here where I presume that Americans want to eat beef the whole year round. And you can fit your date of calving with different groups of animals to manipulate your demand curve as you want. How much thinking have you done about this whole business?

Blaser. Very much, and our newest work is a contract of $192,000 which we won from the Federal Government, in which we're doing just that. We are already planning in this system to market fat cattle in July. As a matter of fact, they ought to go to market anytime they're fat and we can help this along with some

grain feeding. Our animal nutritionists say for young animals we'll have to have some grain supplementing—no more than 1% of bodyweight—in order to get the carcass grade we need, and I agree with them.

One word about put and take. I did not mean that McMeekan used the put and take, but he used the principle of put and take. In other words, I don't look at put and take as changing animals frequently, only very infrequently. When you shift land needs as McMeekan did, he pulled out 40% of the area for harvesting silage in the spring and something like 40 to 50% for accumulated grazing in the fall. We could call this feed budgeting, but the whole point is that he utilized the forage by shifting land areas and this is what the put and take is to me. This was helpful to us in making judgments on what stocking rates to use. And we didn't miss it too badly except we were on the conservative side.

John Balasko (West Virginia, USA). We're finding that the longer we accumulate tall fescue into the winter season the lower the digestibility and I would like for you to elaborate on your statement that the longer you accumulate tall fescue in a fall-winter system the higher the digestibility. We're finding that fructosans leach from the tissue and lower the soluble carbohydrate concentration and, as a result, our digestibilities are lower.

Blaser. I agree with you. Dr. Ed Rayburn is working on this very problem. The first work that Brown did was to accumulate tall fescue from early September onwards. After some ten weeks, the digestibility increased, believe it or not, in the realm of 70%. The next year he started accumulating from early August onward, and the digestibility was in the realm of 62%. I believe that if you start accumulating from June or July onward, the digestibility will be more nearly 55%. The whole point is that as soon as you get cold weather and some of the leaves fracture, then soluble carbohydrates leach out. Our data would show that you accumulate around 30% carbohydrates. Taylor, in a Ph.D. thesis, has shown that this declines as the season goes on as cells are ruptured and apparently the soluble carbohydrates leach. However, we don't know the full story on that.

Balasko. We have accumulated from the first of September, the fifteenth of September, and from October 1 or September 30 and what we have found is the later we begin accumulation the higher the digestibility of the forage in the winter period. But we have noticed from September 1 to September 30 there has been a decrease in digestibility of the tall fescue forage.

R. Brougham (New Zealand). Roy, congratulations on a paper that has helped me understand better than ever what has happened when you managed pastures of different composition in this area of the U.S. I think one of the overriding factors that was disguised by some of your data and is a very critical factor in the management of pasture in New Zealand is the mechanism that plants have for survival and our need to recognize these in our management systems. I'm referring particularly to the position of the growing point, especially in plants that have a lot of tillers, that go up to reproductive growth. We graze our pastures tighter than you do yours and we can drastically affect persistency of desired species for, say, winter growth by the height to which we graze our pastures. You opted strongly for the Kentucky bluegrass-trifolium swards, and it seems to me that in this area of the country these are the ones that can take most abuse because they're both stoloniferous. They can stand these mismanagement systems that I think do occur in this region at times. It's a comment I make because I think it is a critical factor in the management of pastures like Kentucky bluegrass-trefolium versus red clover and orchardgrass.

Blaser. Your observation is excellent. Stockpiling fescue has a serious lethal effect on shoot populations.

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Animal Production Systems from Hill Country in the United Kingdom

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The term hill farming is commonly used to define both hill sheep farming and upland farming in Great Britain. Upland farms, on the whole, have much more enclosed sown pasture, and cattle are much more important contributors to farm income, whereas the land resources of hill sheep farming are mainly rough grazings, i.e., uncultivated natural pasture, where sheep are more important than cattle. There is much variation in the land resources and production systems employed within each of these two farming types and they present quite different problems.

This paper is concerned with hill sheep production from self-replenishing stocks of sheep of the hill breeds maintained mainly on those areas of the country designated as rough grazings. In broad terms some 11 million acres of rough grazings in Great Britain are devoted to hill sheep production. This land carries some 5 million sheep on approximately 5 000 farms, most of which are in Scotland, northern England, and Wales. Statistical information specifically describing hill sheep farming is difficult to isolate from the body of official statistics. The difficulty is further compounded by important differences in the categorization of the various farming types as between England and Wales on the one hand, and Scotland on the other. For this reason most of the following data has been drawn from the Scottish statistics. It should be kept in mind that cattle tend to be more important on hill sheep farms in England and Wales than in Scotland, and farm size tends to be significantly smaller in Wales, and to a lesser extent in England, than in Scotland.

The average Scottish hill sheep farm carries a self-replenishing flock of some 900 ewes of one or other of the hill breeds on approximately 1 660 ha and also supports 25 beef cows. Around 97% of the land resources are rough grazings and a large part of the remainder is sown grassland (McEwan and Whitehouse, 1972).

Within the country there are considerable variations in hill soils and climate which give rise to wide differences in vegetation cover. The lower rainfall and better soils of the south and east are associated with a more grassy hill vegetation in which *Agrostis*, *Festuca*, *Nardus*, and *Molinia* species are important. The higher rainfall and poorer soil parent material in the west and north lead to peat formation and a vegetation cover in which *Calluna vulgaris*, *Eriophorum* species, and *Tricophorum* predominate.

These differences in vegetation are reflected in sheep carrying capacity. The better of the grassy hills have a year-round stocking of one ewe to less than 0.75 ha; the predominantly blanket peat grazings of the wetter west often carry less, sometimes much less, than one sheep to 1.5 ha. Approximately one-third of the total hill sheep population of Scotland is stocked at one ewe to between 0.8–1.2 ha (Cunningham, Smith, and Doney, 1971).

These large differences in stocking rate are reflected much more in average area per farm than in average flock size. For example, the average farm is around 830 ha in southern Scotland and farm size increases towards the north and west to reach 5 000 ha in Sutherland (Scola, 1965). The variations in regional average flock are relatively small at around 850–1 000 ewes, but great within-region differences occur in both farm and flock size.

Output per farm is influenced by individual sheep performance as well as by flock size and a major determinant of sheep performance is lambing percentage. A general indication of the lambing performance of the Scottish hill sheep flock can be obtained from the June and December statistics of the Department of Agriculture for Scotland. The crude lambing figures derived from the ratio of sheep under one year old in June to the number of breeding ewes present in the previous December gives a value over the years of around 80%.

Quite large regional differences in lambing performance exist, ranging from 65–70% to over 100%. The poorer land carries fewer ewes, and those ewes produce fewer and less hardy lambs.

Year-to-year fluctuations in lambing performance within regions also are of importance. For example, the same group of 16 farms in southeast Scotland produced figures of 85%, 74%, and 87% in 1968, 1969, and 1970, respectively (Anon., 1972).

Most of the lambs from hill sheep farms are sold as stores for fattening on farms at a lower elevation. In southeast Scotland approximately 80% of lambs sold are sold as stores; the corresponding figure for the north of Scotland is upwards of 90%.

Within their size classes as determined by a labor input scale, hill sheep farms show levels of net

income (which includes return on tenant's capital) substantially lower than most of the other types of farming in Scotland.

An examination of the various performance measures calculated and presented in successive volumes of Scottish Agricultural Economics since 1967 tends to support the view of Allan (1973) that the heart of the economic problem of hill and upland farming lies in the small size of the farm business. Gross output per £100 input is, on balance, slightly higher in hill sheep farming than in other types of farming. Net income per £100 gross output is comparable with that of other types. Gross output per £100 labor is, however, significantly poorer than in most other types of farming. But machinery and power costs are of a much lower order in hill sheep farming, reflecting the difficulty of mechanizing the work, and gross output per £100 labor and machinery is very similar as between hill sheep farming and other types. The return on tenant's capital (calculated as management and investment income as a percentage of tenant's capital) at 10% is also very similar to the general rate of return in Scottish agriculture (McEwan, 1971).

Farm business size can be increased through the acquisition of more land or by intensification within existing units. Harkins (1970) has discussed the question of the amalgamation of holdings in hill sheep farming. In his view, where this can be done by renting additional land, especially where such land is contiguous with, or in the neighborhood of the original farm, amalgamation may be an attractive possibility, but where the extra land has to be acquired by purchase using borrowed money serious difficulties are likely to be encountered in servicing the investment.

A more widely applicable way to increase the size of the hill farm business is through intensification. Intensification for present purposes may be defined as increasing output in a way that is economically worthwhile to the farmer who undertakes it. In approaching the problem of intensification a first requirement is an adequate analysis of the problem in biological terms.

ANALYSIS

The output of sheep product per unit area varies greatly from one hill region to another, but, in general, it is low, averaging around 15 kg of weaned lamb live weight per ha. This is partly a function of the low stocking rates previously referred to, but it is also a consequence of poor levels of individual sheep output, averaging around 18 kg weaned lamb live weight/ewe/annum.

Despite the variations that occur in management practices from one hill farming region to another, hill sheep farming systems in Britain have several important features in common. The major one is the fact that the sheep are (perhaps uniquely in ruminant animal production systems in Europe) set-stocked in a free range grazing system and expected to obtain the large part, if not all, of their nutrient intake from grazed pasture the year round.

This kind of grazing system takes place against a background of poor levels of pasture production, perhaps averaging some 1 800 kg DM/ha/annum. Pasture production is highly seasonal and the growing season is of less than six month's duration.

An examination of stocking rates in relation to pasture production indicates that overall levels of pasture utilization are poor; they seldom exceed 20% and are usually much lower. In explanation, the argument can be offered that stocking rates are set at levels which will provide enough diet selection opportunity to afford the sheep a minimum tolerable level of winter nutrition. But stocking rates so set lead to a substantial underutilization of the summer pasture growth. The surplus accumulates during the summer, its quality deteriorates, and the material from which the sheep has to select its winter diet is already of poor quality at the beginning of winter. This, in turn, determines the need for a high degree of selection opportunity. Hence, the low stocking rate, and the cycle continues.

Ingested pasture quality is at best moderate, partly as a result of the intrinsic nature of many hill plant species and partly as a consequence of the fact that even those pasture types which are of relatively high nutritive value have a high proportion of unutilized poor quality material.

An examination of the poor levels of individual sheep performance demonstrates that at each and every stage in the annual production cycle nutrition is a limiting factor of performance to some aspect or other. The poor cyclical patterns of nutrition characteristic of traditional hill sheep farming give rise to a cycle of sheep body weight and condition that is substantially poorer than that consistent with good individual sheep performance.

Fertility in hill sheep is variable but, in relation to the genetic capacity of the breeds of interest, it is generally low. Ovulation rate in these breeds is a function of body condition at mating which in turn is a consequence of the general level of summer nutrition (Gunn and Doney, 1970).

The end of pregnancy coincides with the end of winter and lamb deaths, often in the region of 15–25%, are high. In many circumstances this is contributed to by the poor climatic conditions at lambing, but a major cause is the combination of poor ewe body condition and under-nourishment towards the end of pregnancy (Russel, 1967).

Lamb growth rates are moderate at around 0.2 kg/hd/day, and this is attributable to inadequate nutrition of the ewe in lactation and to the moderate

quality of the pasture feed ingested by the lamb (Peart, 1970).

BIOLOGICAL POSSIBILITIES

Increases in animal output per unit area require improvements in individual sheep performance and/or increases in stocking rate. Individual animal performance improvement requires improvement in the various components of performance. At least some of the breeds of interest, for example the Scottish Blackface, are capable of levels of fertility in the region of 170%. Fertility is very responsive to better body condition at mating and this requires nutritional improvement for at least some part of the recovery period between early lactation and mating (Gunn and Doney, 1970).

Lamb survivability at around birth can be increased and lamb death rate reduced, often to below 10%, by better ewe nutrition in late pregnancy (Russel *et al.*, 1974). Lambs of the hill breeds can achieve growth rates at least twice those obtained on the hills and lamb growth rates on the hills can be improved by better ewe nutrition in lactation and better quality feed for the lamb (Peart, 1970).

Stocking rate increases require higher levels of pasture production and/or improvement in the efficiency with which the existing indigenous pasture is utilized. Pasture production can be increased by improving soil nutrient status (mainly calcium and phosphorus) and by the replacement of indigenous species by sown grasses and clovers. Yield increases of two to threefold and often more can be achieved by means of a range of hill land improvement techniques applicable to a wide range of hill soils and vegetation types (Newbould, 1976). Improvements in pasture quality will almost invariably follow the replacement of indigenous pasture by sown grasses and clovers.

The extent to which improvements in utilization and pasture quality can be obtained on indigenous hill pastures varies considerably from type to type. On *Agrostis-Festuca* pastures, for example, high levels of pasture utilization have been shown to be possible and to result in regrowths of quite high quality pasture (Eadie and Black, 1968). On the other hand, better utilization of *Nardus* and *Molinia* dominant grass heath gives rise to a considerable short-term nutritional penalty to the stock and to a less productive and nutritionally poorer pasture than that obtainable with *Agrostis-Festuca* (Floate *et al.*, 1972). The more valuable species of the vegetation of blanket peat are likely to be grazed out at quite low levels of pasture utilization, although much higher levels than those currently attained are possible. Little nutritional improvement is to be expected, however, on blanket peat.

In general terms there are opportunities for improving the utilization of a wide range of indigenous pasture types by several fold and some limited scope for improvements in pasture quality.

SYNTHESIS

The synthesis of improved systems has to take account not only of the biological possibilities for increasing output but also, if it is to be of practical value, of a variety of important constraints of a non-biological kind.

For example, hill land improvement requires access and a terrain on which tractors and fertilizer spreaders, and sometimes cultivation equipment, can safely be used. These factors inhibit reseeding of large parts of many hill farms. Labor costs are high as proportion of total costs in hill sheep farming and skilled labor is a scarce commodity. Improved systems must seek to provide a framework within which labor can be more efficiently used.

Economic constraints of a variety of kinds have a major effect on the extent to which some of the biological possibilities can be employed. It is, for example, technically possible to improve nutrition at any time of the year by means of concentrate supplements, but relationships between concentrate costs and product prices serve to limit concentrate use very severely. Off-wintering offers a very effective means of increasing output from the hills but the large increases in winter feed costs incurred render it uneconomic.

Even if physical factors do not limit the amount of land on a hill unit which can be improved, economic factors usually do. Land improvement is expensive and borrowed capital is expensive; borrowings have to be serviced. Studies of cash flows of the development of improved systems of production demonstrate quite clearly that beyond a certain point investments in land improvement can lead to cash flow problems which may bankrupt the enterprise (Maxwell *et al.*, 1974).

The synthesis is therefore an attempt to take as much advantage as possible of the biological possibilities within the framework set by physical, economic, and operational constraints.

Increases in output of sheep product can come from improvements in individual sheep performance and increases in stocking rate. Sheep performance improvement requires improvements in feed quality in summer, particularly during lactation and in the pre-mating period. Late pregnancy nutrition can only be improved by means of concentrate supplements, but hill pasture improvement will contribute to improved summer nutrition. Pasture quality can be improved on some indigenous hill pasture types, notably *Agrostis-Festuca*, by management means.

Increases in stocking rate can come from increases in pasture production or from more efficient use of existing indigenous pastures.

The first major point which emerges from these

various considerations is the need for land improvement. It is equally clear this can only be carried out, initially at least, on a part of a hill grazing unit. The basic concept is, therefore, of a system comprising two components—an area of improved pasture and a remaining unimproved indigenous hill pasture.

The second major point is the need for a management strategy on which to base the integration of these two pasture components in a whole and continuing grazing system.

The improved pasture component will invariably provide feed of high quality. It is logical to attempt to use this better quality feed so as to maximize its impact on individual sheep performance. This suggests that it should be used to contribute as much as possible to the improved nutrition during lactation and lamb growth, that is, from May to early August, then after a rest period during which the mid-to-late season growth is accumulated *in situ*, the regrowth will be utilized in the several weeks before and during mating which takes place in late November. During the mid-summer period, after the lambs are weaned, all ewes are returned to the unimproved hill which is also utilized after mating for the winter period until lambing.

Within this overall strategy other objectives are important. These include the achievement of a high level of utilization of the improved pasture component, and increased utilization of the primary production of the indigenous pasture area, short of endangering its long-term ecological stability and short of inducing a counter-productive and damaging nutritional penalty to the grazing stock.

This synthesis is currently being tested in large-scale studies in the Hill Farming Research Organization and some of this work is described and some results are discussed elsewhere at this Symposium.

THE MANAGEMENT STRATEGY, STOCKING RATE AND SHEEP PERFORMANCE

In the development of improved systems of hill sheep production there is no alternative to a two-pasture system. It follows that a management strategy on which to base the integration of the two components is necessary. The management strategy described here is almost certainly not the only one which could be advanced but it does have the merit of being based on, and supported by, a good deal of firm experimental evidence.

It is not suggested that alternative strategies will not give rise to increases in output nor is it suggested that these increases will not be profitable. Implicit in the argument, however, is the assumption that on current knowledge this is the strategy which will maximize the response to a given input of improved pasture. This assumption remains untested largely because no coherent alternative strategy has, as yet, been advanced. In some circumstances, however, the use of some part of the improved pasture component for lambs in the post-weaning period, which would involve some sacrifice in the amount of improved pasture available to the ewes in the pre-mating period, requires examination.

The synthesis offered here was developed to deal with the problems of extensive hill grazing units and management systems largely based on indigenous pasture where the improved pasture component, initially, is likely to be limited in relation to ewe numbers. But it should not be assumed that further increments of improved pasture will necessarily always be best integrated with the unimproved hill within the above described strategy. From the point at which the improved area becomes more than sufficient to provide all ewes (and lambs) with improved pasture from parturition to weaning an important choice has to be made. The choice is between maintaining the management strategy (in which case stocking rate has to be increased to fulfill the objective of full utilization of the improved pasture component within the periods of use dictated by the strategy) or maintaining stock numbers at their current level and extending the period of improved pasture utilization beyond weaning (which implies a significant departure from the proposed management strategy).

On many hill farms, because the area of improvable land is severely limited by reason of topography and/or access, the issue will not arise. On others a point may be rapidly reached at which further increases in output may place demands on labor or some other component of the fixed cost structure which will render a further phase of improvement so expensive as to be not worth considering.

The nature of the biological relationships between successive increments of input and the consequent increments of output may, whatever the management strategy, give rise to a steadily diminishing economic response. Current studies have not yet gone far enough to be helpful in supporting or rejecting this hypothesis, but it is not unlikely that the first input of improved pasture will give rise to a response in animal output which includes, particularly with some indigenous pasture types, a significant contribution from improved utilization of the indigenous pasture component. But successive inputs of improved pasture may contain less and less of a contribution from this source.

Assuming that no prior physical or economic barrier to further land improvement is encountered it can be postulated that, in the context of the proposed management strategy in all environments at some point, the next increment of improved pasture will give rise to a more or less sharp fall in animal output response. Further increments of improved pasture will usually lead to a need to

increase stocking rate which will in turn create an increase in grazing pressure on the indigenous pasture component. There must necessarily be a limit to the grazing pressure any indigenous pasture type will tolerate and this limit will become apparent in one of two ways.

The first is ecological where grazing pressure reaches a level at which the indigenous vegetation can no longer be sustained. Undesirable vegetational change resulting from increased grazing pressure on the vegetation of blanket peat has been described by Grant (1976). Knowledge gained from descriptive studies of the dynamic ecology of hill pasture types (King, 1965) and from experimental studies (Eadie, unpublished) indicates that some types of vegetation, for example *Agrostis-Festuca*, are extremely stable in floristic terms in the face of high levels of pasture utilization and that others, for example some *Molinia* dominant pastures, may even respond in terms of desirable vegetational change.

The second major reason which can set limits to grazing pressure on the indigenous pasture component is nutritional. One way in which this can occur is where increases in grazing pressure lead to the ingestion of very poor quality feed. It has been shown, for example, that increased utilization of *Nardus* dominant hill pastures is accompanied by a severe nutritional penalty (Floate, Eadie, Black, and Nicholson, 1973). And in the absence of such a penalty grazing pressure can be taken to the point at which the amount of available feed becomes insufficient to support acceptable levels of nutrition.

The fact that further development within the current management strategy is inhibited at some stage does not mean that further land improvement cannot be expected to promote profitable response. But the management strategy from that point on must take account of the new situation and further increments of improved pasture will have to be used, in part at least, to reduce grazing pressure on the indigenous pasture component to a level which is ecologically, or nutritionally, acceptable.

In practical terms the implication is the use of improved pasture for a longer period during the summer. While this will not inhibit further increases in stocking rate, its impact will be mainly on individual sheep performance. Another implication will probably be the need for an increased contribution of feed from other resources in winter which will require an increased per animal output to justify the extra costs.

These management changes lead to a system in which sown pasture plays an increasingly important role and where the indigenous pasture component becomes of secondary importance. With further land improvement the nutritional environment will become capable of supporting a more productive crossbred ewe flock. In other words, a logical extension of the change in management strategy is an upland sheep production system.

While a change in the management strategy must be made in response to the above described events, as suggested earlier it is possible and it may be better to make it earlier. In the last analysis the decision is an economic one which turns to an important extent on the relative responses in terms of both output and costs to unit increase in the amount of improved pasture in any given situation.

The impact of unit amount of improved pasture on performance tends to be greater at lower levels of performance. It is easier to increase weaning percentage from 65 to 95 than it is to increase it from 95 to 125. One reason for this is that beyond 90% further increases in individual animal output inevitably mean more twin-bearing ewes. The twin-bearing and rearing ewe is a much more demanding animal nutritionally, and twins tend to be less well grown at weaning than single lambs in the same environment.

At lower levels of performance the contribution to output of a given increase in stocking rate is much smaller than at higher levels of performance so that in output terms the balance of advantage will tend to favor increases in stocking rate as performance improves. But cost increases also must be taken account of and both improved performance and stocking rate increases tend to bring in their train increased winter feed inputs.

On present knowledge it is not possible to give the necessary quantitative expression to these various key relationships. But current work on hill pasture evaluation, diet supplementation, the performance of hill sheep and their crossbred derivatives together with the continuing program of hill and upland systems studies of both a practical and theoretical kind will, it is hoped, contribute to our ability to quantify at least some of these issues in the future.

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DISCUSSION

K. O'Connor (New Zealand). Gaul does have three parts and I want to ask you please to help us for the next century in New Zealand, and I think for the next millenium in the rest of the world, about the incorporation of the third part which was your winter supplementary feeding. Briefly, we are at the present time contemplating the introduction of higher lambing percentage Merino sheep into our high country. We know that we can supply the nutritional needs during spring of the higher lamb crops; we know that we can supply the nutritional needs for maternal tissues in the pre-mating period because that's what our curve demonstrates. Now, from your understanding of the biology of the thing, what's the sensitivity of the system? How much do you profitably expose yourself to a greater winter feed need by way of the third part of Gaul, the supplementary feeding, the high fossil fuel energy input involved in the thing and still exploit that extra thing?

Eadie. It's a very bold man who says anything very specific about another man's environment. I think in your case Gaul is indeed divided into three parts. I suggest we do this sort of thing because we are dealing with sheep which are pretty resilient to the winter feeding situation; if we can pack on enough body condition, we can get through the winter—so far—with grain-based supplements in limited quantity. But you have the great advantage that we don't have in many situations in that you have some flat land, and this can be used to provide winter feed—either grass which is cut and stored in some fashion or, alternatively, conserved *in situ*. In our more fragile environments we might consider limiting the grazing pressure on some of our sensitive areas to achieve the same end. But I wouldn't know what crops you might want to use here, or how much you might need.

O'Connor. But it's the animal biology sensitivity that I'm concerned about.

Eadie. Unless I know more precisely what sort of nutritional level we are encountering I'd be unable to offer a view on the magnitude of supplement that is necessary, but if you're at a poor nutritional level, then the system is very sensitive indeed to the need for an improvement at this particular time.

O'Connor. Can I put the question more simply? In your context, how much extra are you needing component three—your concentrate feeding—because you've moved into a higher fecundity range by your spring, summer, and autumn nutrition?

Eadie. Quite an extent. In broad terms, moving fertility up from something like 60% to 90% leads to a requirement of approximately 30 lb concentrate extra. If we were in turn moving that up to a higher proportion of twins, to a potential lambing percentage of 120%, I would think that we would get close to doubling that quantity. But I don't have the basic information that would enable me to do this sort of calculation for your situation.

R. Brougham (New Zealand). I would like to ask a similar question differently. I think that what's critical in your concept is the proportion of 2:1, and I would like to know whether you have looked at this proportion, because obviously this is going to affect the amount of feed produced for the flock through the year and you can relate the proportion of one to the other in terms of when, for example, you don't need too much feed per animal, or when you do need more feed per animal. So have you looked at the proportion of 2:1, and how significant is this?

Eadie. I think that we would rather look at it, not in terms of the proportion of 2:1, but as the amount of 2 that you have per unit of livestock. The proportions don't really signify very much in this enormously variable situation. But starting off and taking all of these considerations together—the need to make a fairly substantial nutritional impact, the need to improve stocking rates—we would need to put something like an acre per 6 or 7 ewes as an initial investment into the system. That's the sort of figure we have in mind for a starting point and that's the sort of thing that will improve performance very significantly. It gets considerably more complex when you decide to extend the area beyond that; the biological consequences will be very different in different circumstances.

119.
Technically Feasible, Economically Marginal and a Social Exercise: Beef Production from Hill Land in Fiji

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The title of this paper was the comment of a member of a feasibility team summing up a hill development project in Fiji; it was chosen here as it succinctly illustrates the problems to be encountered in hill land development both in Fiji and many other countries.

PAST HILL LAND USE

The history of animal production in Fiji is comparatively recent, as there were no ruminants on the islands until the last century when they were introduced by Europeans. Hill land was not extensively used for cattle raising until the 1920's when several European settlers obtained grazing leases for many thousands of acres of the better-class rolling country in the coastal hinterland around the main island of Viti Levu.

Large areas were planted in the semi-improved creeping grass, *Dichanthium caricosum*, for grazing with European breeds of cattle. On the north coast, at Yaqara, the Colonial Sugar Refinery Company (C.S.R.), which operated all the sugar mills by this time, established a ranch of some 6 500 ha, of which 1 000 ha were alluvial flats and the remainder mainly rolling slopes, to supply meat to their employees. During the Depression of the 1930's beef prices dropped so low that nearly all the ranches failed, leaving only the C.S.R. ranch in the post-war period.

The other sources of beef in Fiji have been surplus draft animals from Indian sugar cane farms, for which Zebu cattle were imported in the 1930's, from copra estates where cattle were used as grass cutters to facilitate nut collection from the ground, and from unmanaged communally owned Fijian cattle in hill country around the villages.

This situation remained static until two hill land schemes were started in the 1960's. One project, at Verata on the wetter (3 000 mm) eastern side of Viti Levu, organized the Fijian landowners to lease blocks of approximately 70 ha each from their communal land to be developed as fattening areas for steers purchased from the drier west. The existing vegetation of reeds (*Miscanthus japonicus*) was cleared by cutting and grazing before planting *Ischaemum indicum* and *Brachiaria humidicola*. This attempt at vertical integration of beef industry was supported by the subdivision of some 4 000 ha of steeper communal land, at Tilivalevu in the drier (1 800 mm) zone in the southwest, into beef breeding farms of 250 ha each to produce store steers.

Although both these schemes are still in operation, they cannot be regarded as highly successful for a number of reasons, including the small size of the original loan which allowed only a very small initial herd, and inadequate training and supervision of the new farmers by the Department of Agriculture.

Beef demand in Fiji is steadily increasing while production has been stable or even declining; the present policy of the government is to increase production, to utilize idle land and generally to assist the rural sector of the community.

THE RESOURCES

Unlike some other countries, Fiji has good agricultural zoning in its drier areas; most alluvial or rolling land of reasonable fertility is arable, mainly under sugar cane, leaving only the steeper slopes unsuited for cropping for animal production with ruminants. While much of this land has no other use, except for forestry on some soils, the rugged terrain markedly increases the problems of development. However, the low altitudes (250–500 m) and low latitude (18° S) in Fiji cause no constraints through seasonally low temperatures. Moreover, the annual rainfall is 1 800–3 000 mm, and there is no severe drought period during the dry season. Any heavier rainfall, as on the southeast of the island, would result in a cover of rainforest and more heavily leached soils.

The existing vegetation on the hills is reeds in the wetter soils and a fire-climax of mission grass (*Pennisetum polystachyon*) on the upper slopes, with forest along the numerous creeks. A program of developmental research has been carried out for about six years on the predominant soil type, locally called a nigrescent hill clay, or tropical rendzina. This typically shows about 25 cm of dark brown clay overlying a C horizon of basic tuff or marl. The thin layer of clay exhibits cracking during the dry season but swells when wet causing poor internal drainage in spite of slopes of up to 30°. The research program has been aimed at solving the nutritional deficiencies for legume growth, selecting suitable legumes and grasses and then evaluating the animal

production of the proposed swards in large-scale grazing trials. The trials have shown that only phosphorus and sulphur, as supplied in single superphosphate, are required on the nigrescent soils to produce excellent growth of the selected legumes, siratro (*Macroptilium atropurpureum*) and stylo (*Stylosanthes guyanensis*), while encouraging the naturalized *Desmodium heterophyllum*. The existing naturalized mission grass has been shown to combine well with these legumes, to be palatable when green and to produce up to 18 MT of grass and legume dry matter/ha/yr in cutting trials. In view of the presence of mission grass and the inability to cultivate the steep slopes to establish alternative grass species, the initial phase of development has been to burn the grass cover at the end of the dry season (October to December) and oversow seed of sirato and stylo with 450 kg/ha of superphosphate. Grazing trials are showing that this results in a sward capable of producing up to 500 kg of live weight gain/ha/yr at stocking rates of up to three steers/ha against 150 kg/ha from unimproved pasture. The local leguminous browse plant, *Leucaena leucocephala*, has also been shown to increase animal production threefold, but it presents management problems with large-scale browsing. In the northeast, the nigrescent soils are frequently intimately mixed with areas of humic latosols, the very low pH of which causes high phosphate fixation requiring a different type of improvement.

Thus the hilly or mountainous interior of the main island is a region of high but unexploited potential.

THE ALTERNATIVE USE FOR FORESTRY

Forestry could be described as the optimal land use in view of the natural climax of light forest in this zone before fire. In the west of Viti Levu the choice of enterprise—forestry or grazing—resolved itself when the growth rates of trees were measured in plots throughout the country. *Pinus caribbea*, the best species in the dry zone for milling or pulp, grows very well on the red or ferruginous latosols but very poorly on the nigrescents. It is now felt that much of this effect is due to the physical properties of the different soils, the latosols being deep and free-draining, while the nigrescents are shallow heavy clays, the cracking of which in the dry weather disturbs the root development of the trees. In many ways this is fortunate as these nigrescents are, as described, of moderate fertility for a legume-based pasture while the latosols are extremely infertile (having a strong phosphate-fixing potential) and naturally support only a vegetation of bracken-fern and poor grass while being very erodable.

The areas of ferruginous latosol and the red-yellow podzolics, frequently of more gentle slope than the nigrescent, are now being planted to Caribbean pine for pulp on a 12- to 15-year rotation.

Dual land use has been shown feasible and will be carried out although it is restricted more by economical than silvicultural or agricultural considerations.

The Forestry Department proposes to graze the natural vegetation under the pines on the latosols to reduce the considerable fire hazards. Only a cattle breeding enterprise could be run due to the poor quality of the feed, while the effect of shade on pasture growth is exaggerated under plantings for pulp due to the high tree density until felling. Within the nigrescent soil regions are areas that should be planted to forest for watershed protection on slopes over 30°. Up to this limit, the hills can be grazed under a sward of the creeping *Dichanthium* as long as the cattle are managed. The problems of afforestation on the upper slopes are exaggerated by the lack of access roads to the small discrete areas, the steepness itself, and the lack or cost of additional fencing to prevent grazing of the young trees. In this type of country, fencing follows the ridges to the hill tops and rarely cuts across a slope to exclude the steepest part. Grazing trials are showing good growth of steers in the improved microclimate under pines on the nigrescent soils, but the economics of planting and later extracting small farm woodlots in this hill country are unfortunately poor.

THE CONSTRAINTS ON DEVELOPMENT

With past experience of ranching and current research indicating the animal production potential, it is now felt that there are few technical problems in converting areas of this land to productive pasture, but there are many problems of an economic and social nature.

The land is communally owned and inalienable, being held in trust for the native Fijian people and administered by a Native Land Trust Board. The most common basic land-owning unit is the *mataqali*, which is usually centered on a village; each *mataqali* may own hundreds or thousands of ha of surrounding land, the best class of which often is in "native reserve," i.e., reserved for subsistence farming for the village and not leasable to outsiders. Due to the long lease periods required for agriculture and with an eye on the future, the landowners are generally unwilling to lease any hill land to outsiders even on a profit-sharing basis, preferring to leave the land idle, possibly for decades, until they are prepared to use it. Thus, any development must be by the Fijians for the Fijians.

Being inalienable, the land cannot be used as security to obtain a loan, so even with the greatest enthusiasm, the landowners would be unable to raise sufficient finance to develop their land—the

amounts required only being available to very large organizations or to governments.

Physical communications are a prerequisite to the development of any new area. While roads may be regarded as a national asset distinct from the agricultural development, the benefit-cost ratio of the hill land utilization has to be calculated in deciding national road building priorities. It is essential that the production potential of the area is realized through the application of sound agricultural management and the continued willing participation of the landowners. Road building is the most expensive capital item in development, the cost being increased by the difficult topography and high rainfall intensities. Roads through hill country generally follow the ridge tops and are reasonably stable, but any feeder roads off the ridges can be very expensive. Rough tracks could be made, but it is accepted that all-weather roads and river crossings to a certain minimal standard are cheaper in the long run due to convenience and reduced maintenance.

The native Fijian people living in the rural areas are healthy and robust by the standards of any country; adult literacy is high, with a well-organized social structure based on a chiefly system. There is a developer's problem to persuade enough well-fed, healthy and happy communal people with few material desires and a fairly benevolent welfare state to leave village life and enter commercial farming of an extensive and isolated nature. While short-term enthusiasm can be easily cultivated, the long-term willingness of the Fijian to participate in such projects is unknown but probably has to be constantly encouraged. This has to be taken into account in devising the program of development.

For successful implementation, the agricultural aspects cannot be dealt with in isolation, and the development form changes from a beef cattle project to an integrated rural development project involving land and watershed development, with communications, social structure changes, and technical and managerial training of the prospective farmers.

SYSTEMS OF DEVELOPMENT

Different systems of development of Fijian hill land are illustrated in separate projects in two areas of Viti Levu. In the northeast, the Uluisaivou project, backed with aid from the New Zealand government, started in late 1975. The Yalavou project in the southwest, backed with aid from the Australian government, now is in a pre-implementation phase.

Large-Scale Ranching

The Uluisaivou project will be an integrated development scheme for a total of some 50 000 ha, involving large-scale ranching, subsistence and cash cropping and eventually large-scale forestry, with beef cattle as the major enterprise and covering 14 000 ha. Within this total area are some 117 different *mataqali* of various sizes which, it is hoped, will eventually form an incorporation of landowners and be able to employ professional, technical and financial management for development.

The landowners' shareholdings in the corporation are issued on the basis of the area consented, and will entitle them to dividends from eventual profits. As a legal body, the corporation is able to raise loans through the Fiji Development Bank and the government of New Zealand, with the Fiji government acting as guarantor. The aid program is now providing expatriate general and ranch managers, which permits a fast rate of development with machinery, labor, and large herds of cattle being used to best effect. So far only a few non-adjacent *mataqali* have consented their land; the remainder probably are waiting to see more progress on the land before following suit. In the long term, it is possible that a *mataqali* may, for some reason, wish to opt out of the scheme and sabotage the project to acheive new aims. The establishment of a regular labor force may also cause demands for industrial or government wage rates, reducing management-employee relations within the corporation to the detriment of profits, causing an income imbalance within a village, and creating a laboring class with no chance of private beef enterprise. To reduce these risks, cropping land has been excluded from the project area, allowing cropping to be the main activity for the people.

The large-scale approach may seem best to those attuned to developed agriculture, but sociologists have recommended that the objective of the rural areas in Fiji should be a community of individual farmers living on or working on holdings but retaining the village communal buildings and services.

Individual Farms

The same approach is being followed in the Yalavou scheme which covers some 96 000 ha in total, of which about half has suitable land classification for grazing. It is similar in the final concept to the previously mentioned Tilivalevu scheme.

Individual Fijians will take leases, through the Native Land Trust Board, on parcels of about 250 ha of their own *mataqali* land. Each will develop his farm on which the profits, after loan repayment and tax, will be his own. While this may also be accepted as a system in some Western countries, there is low selection pressure for potential farmers within the *mataqali* rather than the high competition by enthusiastic and experienced young men as on settlement schemes in New Zealand. In the Tilivalevu scheme, new farmers were of unknown agricultural aptitude and as the native land offers no security, the development bank was unwilling to loan them sufficient money. This restricted the rate

of development which was aggravated by the slow initial return from a beef breeding enterprise, so that the farmers have been unable to make a decent living. In the new project these risks will be minimized, as during the first five years of a farm's development the prospective farmer will be trained and paid a training grant while working on the land. At the end of this period, the individual's suitability will be assessed and, if satisfactory, he will be given the lease of a farm sufficiently developed for an immediate income. On a project scale, this prejudices economic viability because the rate of build-up of cash flow is retarded by the time needed for the acceptance of new ideas by the farmer. On the farm, the level of technical efficiency is likely to be considerably lower than on the professionally managed ranch, especially in the initial years, while there is a labor restraint in using family labor to avoid excessive costs.

There is a significant direct cost of training and social development due to the higher requirement for supervisory and training staff to deal with 60 individual farmers in an area equivalent to that managed by one ranch manager. The erection of housing for these staff and the construction of a rural community center at the training farm is costly; the salaries of local and expatriate staff over the ten-year development period amount to nearly 20% of the total project costs and exceed the total farm development costs over the same period. In the longer term this form of development may be more stable as the farmer has a personal interest in the land, although the farm size suitable for rapid development is smaller than that needed for sufficient income in the future. It is also important that the farm lease remains intact on the farmer's death, to avoid fragmentation.

ECONOMIC RETURNS

The Uluisaivou large-scale scheme should show a cash surplus by year seven, with an internal rate of return taken in perpetuity at 12%, if road building is charged to the nation.

In the Yalavou individual farm scheme there is an on-farm financial rate of return, with present subsidies, of about 20%, this high figure being partly due to the negligible cost of land. However, the whole project economic rate of return drops to about 4.5% with the costs of infrastructure and training included.

These rates of return are considered marginal by international development agencies.

BEEF PRODUCTION AND PASTURE IMPROVEMENT

Although Fiji has several breeds of cattle (Brahman, Santa Gertrudis, and local crossbreds) suited to the local conditions, these are not noted for their reproductive capacity and the national herd of Fiji has not been increasing fast enough to provide the large numbers of stock needed for these large beef schemes. It will be necessary to import suitable animals from Australia, the extra cost of which will be borne by the aid donors but which still has to be charged at national prices. In both schemes, the principal aim is the production of beef in a normal ranching manner although with different herd sizes.

Breeders will be mated seasonally to calve at the beginning of the wet season and the calves will be weaned at the start of the dry. Thereafter a post-weaning growth check is common on natural pasture but it can be prevented with the use of *Leucaena* browse legume in weaning paddocks. Unimproved pasture is only suited to store steer production, but, with improvement it enables steers to be fattened and to reach slaughter weight at 2 ½ years of age. Fattening all the steers in other wetter zones will not be possible with the large numbers that should be available from both schemes and the forest grazings. This form of integration markedly reduces the profits to farmers because of double transport charges that can exceed 10% of the final price. No feed-lot finishing is envisaged at present because of the high cost of grain and concentrates and the lack of suitable arable land on which to grow them. It is possible that sugar cane, fed as decorticated "Comfith," could be used if the export price for sugar fell sufficiently low for this to be economical.

The comparatively large areas of improved pasture needed for the breeders and fattening steers pose two immediate problems, namely the price of superphosphate and the means of its application to steep hill land. At present, single superphosphate is imported into Fiji in bags, resulting in a national price of F $140 per ton, of which 60% is for shipping. The economics of pasture improvement for fattening steers still appear viable due to a government subsidy on fertilizer and the low maintenance dressing required, but large savings could be made by bulk shipping. The recent development of "Biosuper" appears to offer even greater savings as the bulk raw materials for superphosphate are presently shipped past Fiji enroute to Australia or New Zealand and could be offloaded. Biosuper simplifies the manufacture of superphosphate in which rock phosphate is treated with sulphuric acid.

With Biosuper, rock phosphate (apatite) and rock sulphur are ground and mixed in the ratio 5:1 before pelleting and inoculation with the sulphur-oxidizing bacteria, *Thiobacillus thiooxidans*. This requires only simple grinding and pelleting machinery and can thus be economic on a small scale. Under conditions of sufficient temperature and soil moisture, the sulphur is oxidized to sulphuric acid which reacts with the apatite *in situ*. Field trials in Fiji's

tropical marine climate are showing Biosuper to be initially slower but then more effective than superphosphate for legumes. The possibility of local manufacture of Biosuper is of great interest in the economic viability of the beef schemes.

If Biosuper is attractively priced and large areas are to be improved with its application, it will be possible to justify an aerial topdressing service which should be the cheapest and most convenient method of spreading, especially when compared to the present system of carrying bags of fertilizer by horseback and bullock sledge through the hills to the paddocks for hand-spreading.

Our beef schemes have now expanded to rural development schemes that are also going to require the establishment of additional service industries for satisfactory performance.

In spite of the many problems besetting both hill land development schemes in Fiji, they stand a good chance of success, with the continued interest of the Fijian landowners, in part due to the sensible attitudes and targets chosen in the assessment of their feasibility. The social problems and land ownership have been recognized and allowed for in the rate of development while the limitations of past projects have been studied. Research into agricultural and technical problems started several years before project implementation and not, as so often happens, after it in a time-pressed salvage operation. This allows more accurate parameters of production to be used in assessment.

In summary, the utilization of hill land in developing countries can rarely be gauged in agricultural terms in isolation from the social aspects and can be economically marginal in terms of total land development.

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DISCUSSION

J. Eadie (Scotland). Which do you think is the more socially desirable of these two activities? With respect to the second, it seems to me one of the consequences would be broken up village structure, or am I assuming too much?

Partridge. Yes, the village structure will be broken up during the week. The people will have to be living on isolated farms which some of them do enjoy, but what we'll do at the local farm and with the villages is to make sure that they can return and keep their church and social activities going. This is a problem, but it has been suggested by a sociologist that this is the way it should go.

D. Plucknett (Hawaii, USA). I was interested in your work with the cattle under the pine trees. I think that some of the other work with cattle under coconuts and some of these kinds of tree crop grazing systems have shown that livestock production need not be lessened by grazing under tree crops and that there really isn't any reason for us to do as much land clearing in some cases as we have done. I think we would be quite surprised with the kind of production we can get in the tropics by leaving more trees and if we do it evenly, we can end up overcoming the problem that Roy Blaser mentioned this morning, which was the camping problem, and this is another thing I felt was interesting. Another comment: I was pleased that hetero came back so well in the heavily grazed areas.

Partridge. Hetero performed well under grazing, not well under cutting grass.

Plucknett. Right. This is very significant because hetero is common in the South Pacific. It would be a reasonably good species to have around if you managed correctly for it.

D. Roberts (Australia). First of all, with the hetero, managing it very short as you must to make it persist, do you get an invasion of weeds?

Partridge. We don't have to manage it that short. That is, the highest stocking rate was one animal to ¾ acre. Now, when we had one animal to 1 ½ acres, we had a more patchy growth which had areas of hetero and areas of Siratro. I found weeds coming into this heavy grazing but the weeds we had were leguminous weeds. With that very dense cover, we kept out nearly all other weeds. We've got a noxious weed called tobacco weed. On chemical analysis, the phosphate levels, the calcium levels all were four times as high as any of the legumes that we've planted. Maybe a few weeds like that make a far more balanced diet than forcing animals to eat what you think they should eat.

Roberts. And the other thing was rock phosphate straight, not Biosuper.

Partridge. Well, I didn't try it because of the big sulphur response that I had previously.

R. Brougham (New Zealand). Two or three comments, then, perhaps a statement that may promote discussion. First of all, your superphosphate prices. If you could manufacture it in your own country, it would be about a third the price. Ours is about $50 per ton and from the same source, I think, Naru, as yours is and about the same distance. So, if you manufacture, it would cut phosphate cost way down. The other comment is that there are a lot of hand

machines that you can strap to your back to blow fertilizers up the hills, and I wonder whether some of these smaller machines could be usefully employed in these sorts of areas. But the third point, and the major point, I want to make is that I see a situation developing in the world, not just for those countries that are starting out on agricultural plans, but also for countries like our own, where we are 80, 90% dependent upon export income from agricultural products. I can't help thinking that for the countries of lesser economic abilities than ourselves at the present time, perhaps some of the best forms of aid could be in the form of transport subsidies to allow these countries to get products to market. Now, with this very large cost there is in transport from, usually in southern hemisphere countries anyhow, distances of 5 to 10 thousand miles, it kills export, it's going to knock us out soon. Our shipping costs are going up and up and we're going to get to the stage where we are priced off world markets. I can't help think that the same will apply to a lot of these other countries.

Partridge. This tends to become political, but I think many subsidies like that tend to go to the ship owners and the price stays the same to the farmers. Beef production in Fiji will only be for the internal market, which means that we can gauge our prices a lot more accurately than we could if we were on an export market. We do export a lot of sugar. I think, rather than subsidies, if one had free competition in the shipping world with wharf labor and no cartels on shipping across the Pacific one could get a lot cheaper freight at the moment. So this is a political problem.

120.
Role of the Soil Conservation Service Plant Materials Work in Developing Plants for Hill Lands

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By combining several disciplines, the Soil Conservation Service provides technical assistance to individuals and units of government to develop sound conservation programs.

One of the disciplines is plant science. Plants—grasses, forbs, shrubs, and trees—are versatile conservation tools. Selected plants help control erosion, increase forage production, stabilize shifting sand, provide wildlife food and cover, and many other benefits, including landscape beautification.

Commonly available plants are used when possible. However, suitable plant materials are not always available to meet all needs encountered in conservation work. For this reason, the Soil Conservation Service operates plant materials centers and employs specialists in developing and using plant materials. They assemble, evaluate, select, and cooperatively release and distribute for commercial production plants for specific conservation uses.

Soil, climate, and conservation needs vary greatly throughout the country. Plant materials centers are strategically located to serve land areas having similar major characteristics. Consequently, results of their comparative plant testing are adaptable and applicable to large geographic areas.

Plant materials centers' efforts are directed to serve the multifaceted disciplines of agronomy, biology, range management, and woodland conservation. Center managers and specialists closely coordinate studies with the other plant scientists working in these disciplines. Since soils are crucial to plant performance, close working arrangements exist between soil and plant specialists. Many conservation problems are solved through the combined use of engineering practices and selected plants, thus requiring coordinated efforts between plant scientists and engineers.

Currently, there are 22 plant materials centers located throughout the United States, including Hawaii and Alaska. A National Plant Materials Center is located at Beltsville, Maryland. It serves as a distribution point for plant materials received from foreign sources.

THE PLANT MATERIALS WORK IN THE SOIL CONSERVATION SERVICE

An unprecedented demand for suitable plant materials was created in the early thirties when the first national organized effort in soil and water conservation was launched. The demand stemmed

from a recognition of the value plants have in conserving soil and water.

As environmental concerns have increased in the United States, the demand for previously developed conservation plants has accelerated. New conservation problems have been recognized. For example, demands for expanded energy sources from surface mining, higher production from grazing land, and a more esthetically pleasing environment greatly increase the role of Soil Conservation Service plant materials work.

Soil Conservation Service plant materials work frequently is conducted in cooperation with other state and federal agencies. This reduces duplication of effort and accelerates the rate of plant testing and development.

Plant materials activities are currently seeding plants for these major hill land uses:

—Stabilization and productive use of surface-mined lands.

—Forages that will extend the season of production, produce superior-quality feeds, more efficiently use marginal land, and give better soil protection.

—Low-volume cover to replace brush on mountain slopes to reduce the possibility of fires that threaten life, property, or result in serious sediment sources.

—Improved wildlife food and cover.

In the search for conservation plants, plant materials centers frequently emphasize the collection and evaluation of previously unused species, rather than placing emphasis on developing cultivars from within a species already used for solving the conservation problem. For instance, let us assume a surface mine reclamation problem could be solved through the use of a more acid tolerant grass. In addition to screening accessions of the grasses currently used on such sites, emphasis would be placed on collecting previously unused species. Such plants may be native, occuring naturally on a problem site, or may be an introduced species collected for potential adaptation.

THE TESTING PROCESS

All plant materials centers follow a similar testing procedure of several steps in the development of conservation plants. The procedure may vary slightly depending on the nature of the problem or the type of plant materials being evaluated. The following outlines the procedure generally used with a specific example of plants recently released for stabilizing acid surface mine land in the eastern United States.

Identify the Problem

First, the conservation problems within the area served by the plant materials center are identified. From this information, needs and priorities of work are determined. Once this is done, a project is initiated to select plants or develop procedures to solve the problems.

Stabilization of acid surface mine spoil below pH 5.0 has been recognized as a problem for years in the area served by the Big Flats Plant Materials Center. Work relative to it was started at Big Flats in 1957.

Collection and Assembly

Plants that may have value for solving conservation problems are collected from many sources. SCS employees or others may make collections of material or naturalized material. In addition, plants may be obtained from foreign sources through the Agricultural Research Service.

Many species of plants were collected for the acid mine spoil problems in 1958-60 at the Big Flats Center. Approximately 500 accessions of 30 species were assembled. Included were a few collections of deertongue (*Panicum clandestinum*) and two collections of bristly locust (*Robinia fertilis*). An additional 50 collections of deertongue were made in 1966.

Initial Evaluation

Species are initially screened in comparison with known standards in rows or small plots. Here, all are eliminated but the few superior plants which appear to have the qualities needed for solving the specific conservation problem.

The deertongue and bristly locust accessions were compared against each other as well as other species used for acid mine spoil stabilization. The principal evaluation criteria for the deertongue was quality and quantity of long-term cover and tolerance to pH below 5.0. The bristly locust was evaluated for speedy spread, pH tolerance, quality of cover, and plant vigor.

Selection and Initial Increase

Only the few superior plants are valuable enough to warrant further testing. Those showing real promise in initial tests are selected and increased for more intensive evaluation.

One bristly locust accession was selected for advanced evaluation. Twenty deertongue accessions were selected.

Advanced Evaluations

Two types of advanced evaluations are conducted. One is to evaluate selected species, and the other is to develop cultural and management studies needed to facilitate successful establishment and maintenance of improved plants.

A. *Selected Species.* Advanced studies are conducted on those plants selected from initial testing. More intensive and quantitative evaluations are made to be sure those initially selected are truly

superior. Selected plants are subjected to intensive comparative studies with commercially available material.

Advanced testing may be conducted on the plant materials center or at off-center sites. The location is determined according to the nature of the evaluation to be made. If the evaluation can best be made on sites that closely resemble the problem being studied and such sites are not available on the center, then off-center sites are used.

The bristly locust was planted on many eastern surface mines. Sites were below and above pH 5.0. It was compared against several species recommended for mine spoil planting as well as against other species selected from the original 1958-60 collection for survival, rate of spread, and vigorous growth. The 20 accessions of deertongue were further evaluated for seed production potential, forage production, disease and insect tolerance, and growth characteristics at the Big Flats Center, as well as growth characteristics, pH tolerance, fertilizer requirements, and persistence of stand on mine spoil sites.

B. *Cultural and Management Studies.* Examples of cultural and management studies are:

— Compatibility of species for extending the grazing season and increasing production on range and pasture land.

— Facilitating seed production of conservation plants.

— Techniques for soil moisture retention and utilization in dry climates.

— Methods for vegetative stabilization of surface mined land.

Such studies may be conducted on or away from the plant materials center.

Large-Scale Increase

Plants that warrant evaluation beyond advanced testing are produced at the plant materials center in sufficient quantity to allow for final evaluation.

Several thousand plants of the bristly locust accession were grown. Based on initial and advanced evaluation, seed of the 20 deertongue accessions were blended into one accession and placed in large-scale increase, which provided several hundred plants of seed for final evaluation.

Final Evaluation

The final evaluation of promising plant materials and/or methods for their establishment and management are conducted in field-sized units throughout the area of their potential adaptation. The plants and methods are compared under actual use conditions to standard varieties and methods under local soil, climate, and land use conditions.

The bristly locust and deertongue blend were planted extensively throughout the eastern coal mining region in large plantings. Emphasis was placed on selecting sites with pH below 5.0. Each planting was made in comparison with a commonly recommended plant.

Release

Superior plant materials are released jointly with cooperating state agricultural experiment stations and other interested state and federal agencies for commercial production and widespread use. Most varieties of grasses and legumes are released as certified varieties. Simultaneously with the release, information is prepared for publication on the availability and use of the new plant.

The bristly locust selection was released by the Soil Conservation Service as "Arnot" and the deertongue blend was released by SCS, Cornell University, and the Pennsylvania State University as "Tioga."

Production and Maintenance of Genetically Pure Planting Stock

The plant materials center, or an agency designated at the time of release, is responsible for maintaining genetically pure planting stock of the improved variety and for making such material available to commercial producers.

Arnot and Tioga are maintained by the Big Flats Center.

Commercial Increase

To be sure supplies of the new plant are available, seed or plant production is encouraged. This may be with resource conservation districts and crop improvement association cooperators or state and private nurseries.

Arnot and Tioga are now in commercial production.

IMPROVED PLANTS FOR HILL LAND USE

The cooperative effort between SCS and other agencies has resulted in the release of 200 conservation plants. Over the years, many have been replaced. There are more than 120 varieties now in commercial production and use in conservation programs. Many of these are for specific hill land use.

"Lana" vetch (*Vicia dasycarpa*) is a valuable forage legume for use in the winter-wet, summer-dry climate of California. Although an annual, it is a reliable reseeder under good management and supplements the native or naturalized grasses which dominate the area.

"Blando" brome is an improved strain of the native soft chess (*Bromus mollis*), which is widely distributed throughout the annual grasslands of California. Not only is it useful for seeding with "Lana" vetch for forage production, it has proved to be one of the most versatile cover crop plants in orchards and vineyards in the hill lands of California.

More than 400 000 ha of surface-mined land have been reclaimed by 22 500 landowners in 1973 resource conservation districts. Much of this reclamation was accomplished by using plant materials developed at SCS plant materials centers. Plants used in the eastern coal mining region primarily for revegetation include "Arnot" bristly locust, "Cardinal" autumn olive (*Elaeagnus umbellata*), "Chemung" and "Emerald" crownvetch (*Coronilla varia*), and "Lathco" flatpea (*Lathyrus sylvestris*).

Plants used in much of the western coal mining region frequently serve to stabilize the spoil and provide forage for grazing livestock. Plants used in the northern Great Plains are "Rosana" western wheatgrass (*Agropyron smithii*), "Critana" thickspike wheatgrass (*A. dasystachyum*), and "Pierre" sideoats grama (*Bouteloua curtipendula*). "Durar" hard fescue (*Festuca ovina duriuscula*) has wide adaptation for stabilizing disturbed areas from Washington to North Dakota.

Plants recently released for surface mine reclamation are "Tioga" deertongue for use on acid spoil in the east and "Wytana" fourwing saltbush (*Atriplex canescens*), which can be direct seeded for revegetation and browse in the northern Rocky mountains.

Examples of grasses developed for use on renovated rangeland in the Great Basin states of the western United States include "Luna" pubescent wheatgrass (*A. trichophorum*) and "Whitmar" beardless wheatgrass (*A. inerme*). "Perla" koleagrass (*Phalaris tuberosa* var. hirtiglumis) is a perennial grass used for extending the grazing season on winter annual ranges of California foothills and coastal ranges.

FUTURE EMPHASIS

It is reasonable to assume that the opportunity still exists to find new plants to do conservation work. The search continues at 22 plant materials centers across the United States. One search is taking place in the Appalachian hill lands.

A major effort is currently under way to select plants for the increased utilization of approximately 342 000 ha of improved pasture land in the Northeast. Much of this land is marginal due to physical soil limitations.

Many plant ecotypes are screened for use on two different soils: shallow to bed rock and moderately well to poorly drained soils.

While climax vegetation in the region is evergreen and hardwood trees, a few native warm season grasses can be found scattered over much of the area from New York to Tennessee. Observations reveal that these plants are capable of producing significant quantities of forage during the summer months when the introduced cool-season species are dormant. The potential commercial use of these plants has not been explored.

Currently, selections of switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardi*), and Indiangrass (*Sorghastrum nutans*) have been made and are now in the final testing stage for improving summer forage on shallow, droughty soils. A synthetic strain of purpletop (*Tridens flavus*) will soon be placed in advanced testing for the same purpose. Crownvetch is adapted to droughty soils and may prove useful as a legume to supplement grass production.

Accessions of zig-zag clover (*Trifolium medium*), kura clover (*T. ambiguum*), and big trefoil (*Lotus uliginosus*) are being screened for use on soils with a fragipan. These legumes have not been used commercially in the Northeast, but they show potential for improving the utilization of poorly drained soils. Limiting cultural factors, such as seed production and proper inoculation, need to be resolved before these plants can be widely used.

Major strides have been made in developing conservation plants. Many of these are used in hill lands of the United States. There continues to be opportunities for plant selection from the diverse plant kingdom.

DISCUSSION

R. Cuany (Colorado, USA). Do you have the inoculum of kura clover and the zigzag clover from the original native home of those species, which is Asia, or are you using materials that are derived from programs at Beltsville?

Sharp. We are using inoculum that has been developed by persons other than ourselves. For example, I believe that some inoculum for zigzag clover has been secured from Purdue University. I do not know their source of the material.

Cuany. In the same line, we are collaborating with the newest of the plant material centers, the one in Meeker, in programs of trying to collect and domesticate some of the Rocky Mountain native plants. Among those are some lupins that we think might be useful in revegetation work in the Rocky Mountain region, including the oil shale area on the western slope.

F. Horn (Oklahoma, USA). Some of the plants that you mentioned are among those that have been grazed out in the past by the influx of cattle that have come onto the plains and through these hills. My question, are such things as Indiangrass, that you mentioned being worked on, a livestock feed *per se*? Is this aimed only at conservation of soil in areas such as roadsides, or is there an effort to identify genetic material that can be used specifically in livestock systems where it will also protect the soil?

Sharp. I believe the answer to both of those questions is, yes. The items that I discussed here, the activity that I discussed, are predominantly for improved forage production and soil protection on these marginal lands in the Northeast. You may be familiar with the grazing habits on much of this land. Not only is the production very poor from them but there is a reasonable amount of soil loss. Now this has a great deal to do with management, so you can understand with the introduction or the use of any of these plants there must be some changes in management. These plant materials are being evaluated for their potential for forage production and soil conservation on grazing land in the East.

121.
Clipping Effect on Stand, Yield, and Quality of Three Warm Season Grasses

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In the Appalachian Region of the United States there are areas that are not producing the desired forage for livestock use, especially during hot summer months. These areas have shallow soils and steep and irregular slopes with high exposure to the sun. To supplement cool-season grasses on them during summer dormancy, warm-season grasses are being used on a limited basis.

This study was conducted over three consecutive years (1972–74) at the Soil Conservation Service Quicksand Plant Materials Center, Quicksand, Ky., located in the moderate continental forest region of the Appalachian Plateau.

The study was conducted to determine the effects of clipping three warm-season grasses: "Kaw" big bluestem (*Andropogon gerardi*), "Blackwell" switchgrass (*Panicum virgatum*) and "Cheyenne" Indiangrass (*Sorghastrum nutans*).

MATERIALS AND METHODS

The three grasses were broadcast seeded in May, 1970, on prepared seedbed plots of 1.3 × 3.0 m, at the rate of 645 pure live seed per square meter. No fertilizer or limestone has been added since the project began. Soil tests at the beginning of the project revealed pH, 6.5; P, 47 kg/ha; and K, 277 kg/ha.

Clipping began in June, 1972, after 90 to 100% stands were established. The clipping schedule included combinations of two clippings per season to one clipping each month during the growing season, June through October. All clippings were made on or as near the 15th of each month as possible.

Two visual stand ratings of percent ground cover of the seeded species were made each year, when growth had stopped in the fall and after growth began in the spring. After samples were clipped, the materials were placed in sealed plastic bags and weighed within 1 hour. Samples were oven dried at 70 C for 36 to 48 hours and weighed again.

A randomized complete block with three replications was used. Big bluestem and switchgrass were clipped at the stubble height of 8 cm, 15 cm, and 23 cm, and Indiangrass was clipped at a stubble height of 5 cm, 10 cm, and 15 cm.

RESULTS

Table 1 shows that big bluestem cut in July and October at 23 cm, the highest clipping height, had the best stand remaining, almost 70%. For the stands remaining in 1974 clipped at all heights, those

TABLE 1. Effect of cutting time and height on stand of "Kaw" big bluestem

	Percent Stand After 3 Years Stubble Height			
Cutting Time	8 cm	15 cm	23 cm	Means*
June & Oct.	57.0	55.2	46.5	52.9 b
June–Oct., monthly	13.8	37.2	54.0	35.1 c
July & Oct.	67.3	69.2	69.7	68.7 a
Aug. & Oct.	57.5	64.2	58.2	59.9 ab
Sept. & Oct.	29.3	38.2	36.5	34.7 c
Means*	45.0 a	52.8 a	53.0 a	

*Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

clipped in July and October were best. Stand means for big bluestem showed a significant cutting time effect. Cutting height had no significant effect on the stand, but cutting time by cutting height interaction did. The poorest stand (13.8%) was a result of clipping every month, June through October, at the lowest clipping height (8 cm).

Table 2 shows that the highest yield for big bluestem was at the lowest clipping height (8 cm), clipped in September and October (6913 kg/ha).

TABLE 2. Effect of time and height of cut on the yield of "Kaw" big bluestem

	3-Year Average Yield Oven Dry Weight kg/ha Stubble Height			
Cutting Time	8 cm	15 cm	23 cm	Means*
June & Oct.	6788	4022	2680	4497 ab
June-Oct., monthly	4210	4131	3298	3880 b
July & Oct.	6337	4274	3345	4652 a
Aug. & Oct.	6622	3371	2485	4159 ab
Sept. & Oct.	6913	3602	2501	4339 ab
Means*	6174 a	3880 b	2862 c	

*Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

This also was one of the poorest stands remaining. Three-year-yield means due to cutting time are significant for big bluestem. The yield of big bluestem clipped every month was significantly lower than that for bluestem clipped twice per year. Clipping height means show that yields were significantly lower as clipping height increased. Big bluestem showed no effect of cutting height by cutting time interaction.

Table 3 shows that Indiangrass clipped in July and October at the lowest clipping height (5 cm) had the best stand at 48%. In fact, July and October clippings were among the best stands remaining in 1974 for all clipping heights. The poorest stands were those clipped in September and October at all cutting heights; this was also reflected in the cutting time means. There was a significant difference in stand due to cutting time. Cutting height or cutting time by cutting height interaction had no significant effect on stand.

Table 4 shows that the highest yield for Indiangrass was at the lowest cutting height (5 cm), clipped in September and October (8214 kg/ha). Again a poor stand resulted from this cutting height and treatment. The 2-year means showed no significant difference in yield of Indiangrass due to cutting time. Means

TABLE 3. Effects of cutting time and height on the stand of "Cheyenne" Indiangrass

	Percent Stand After 3 Years Stubble Height			
Cutting Time	5 cm	10 cm	15 cm	Means*
June & Oct.	43.8	26.3	19.3	29.8 b
June-Oct., monthly	19.5	30.7	45.5	31.9 b
July & Oct.	48.2	43.5	44.3	45.3 a
Aug. & Oct.	15.5	23.2	29.0	22.6 bc
Sept. & Oct.	8.5	10.3	16.5	11.8 c
Means*	27.1 a	26.8 a	30.9 a	

*Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

TABLE 4. Effect of cutting time and height on the yield of "Cheyenne" Indiangrass

	2-Year Average Yield Oven Dry Weight kg/ha Stubble Height			
Cutting Time	5 cm	10 cm	15 cm	Means*
June & Oct.	6858	3603	2623	4361 a
June-Oct., monthly	6685	4385	3937	5003 a
July & Oct.	6374	4721	4487	5194 a
Aug. & Oct.	6753	4614	3202	5156 a
Sept. & Oct.	8214	4256	2881	5117 a
Means*	7157 a	4316 b	3426 c	

*Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

for cutting height showed that yields were significantly different. Production decreased as cutting height increased. Indiangrass showed no response to cutting height by cutting time interaction.

Table 5 shows that the best stands of switchgrass at the termination of the study were in plots clipped in August and October at all clipping heights. Clipping in August and October at a height of 23 cm resulted in best stand, almost 91%. Cutting time, cutting height, and cutting time by cutting height interaction all had a significant effect on stands of switchgrass. Clipping during July and October and August and October at all heights resulted in the best stands. Cut-height had a significant effect on stand; the better stands were those clipped at 23 cm.

Table 6 shows that 3-year-yield means for switchgrass were significantly different for cutting time

TABLE 5. Effect of cutting time and height on the stand of "Blackwell" switchgrass

	Percent Stand After 3 Years Stubble Height			
Cutting Time	8 cm	15 cm	23 cm	Means*
June & Oct.	70.2	74.7	62.7	69.2 bc
June-Oct., monthly	8.7	40.3	62.2	37.1 d
July & Oct.	78.2	77.5	72.7	76.1 ab
Aug. & Oct.	80.8	81.2	90.8	84.3 a
Sept. & Oct.	54.2	59.3	66.0	59.8 c
Means*	58.4 b	66.6 ab	70.9 a	

*Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

TABLE 6. Effect of cutting time and height on the yield of "Blackwell" switchgrass

	Year Average Yield Oven Dry Weight kg/ha Stubble Height			
Cutting Time	8 cm	15 cm	23 cm	Means*
June & Oct.	6852	4712	3363	4976 b
June-Oct., monthly	4325	4235	4337	4299 b
July & Oct.	7415	6370	4899	6288 a
Aug. & Oct.	9037	5347	4407	6263 a
Sept. & Oct.	6605	4300	3122	4676 b
Means*	6847 a	4993 b	4026 c	

*Means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

and height. The highest yield for switchgrass was obtained at the lowest clipping height (8 cm), clipped in August and October (9037 kg/ha). Bear in mind that this was one of the better stands remaining. July and October and August and October were the most productive harvest dates. Cutting height by cutting interaction had no effect on switchgrass production.

PROTEINS AND DMD

Cutting height had no significant effect on protein content or DMD (dry matter disappearance) for all species. Cutting time had a significant effect on protein content and DMD. This effect was apparently due to the variable amounts of unseeded species in the samples.

DISCUSSION

G. Jung (Pennsylvania, USA). The management normally used with cool-season grasses when applied to these warm-season species is a sure way to knock them out. We've noticed in our grazing trials, which come pretty close to simulating your July, October clipping treatments, that all cultivars are not responding the same way. For example, it would appear to us at this time, and this is only the second year of grazing, that Kaw big bluestem is not as tolerant of the July grazing system as is the New York 1145 that you people provided. I don't know whether this is due to time of heading or not but the New York strain heads quite a bit ahead of Kaw and I wondered if you've had further experience that would confirm this?

Henry. I think that's right. We tried to select for a late-maturing big bluestem but the one we selected seemed to have a low viability and it was very hard to get germination on it although it was much later than strain 1145 and also Kaw. Kaw is a real good emerging bluestem and has good seedling vigor, but it is just a little bit earlier than what we thought we could use in these supplemental warm-season grasses to go just a little bit further into August.

Jung. Under our conditions, several hundred miles north of yours, the 1145 would be headed about July 20 and then the Kaw would not be heading until sometime in early August. It seemed to me that the Kaw was more sensitive to the July management under our conditions, perhaps because it was in the early jointing stages or at least in the middle of jointing, without any head showing at the time we imposed the July grazing management.

Henry. It's as though your grazing at the Western Pennsylvania Forage Farm was similar to our clipping study in this period of July and August. Switchgrass will go just a little bit further than that particular species, Kaw. I would assume maybe you could go just a little bit further into August in Pennsylvania than you could at Quicksand, Kentucky.

Floyd Horn (Oklahoma, USA). We work with the same grasses some and I'm especially curious about your dry matter digestibility values with respect to clipping height. We always find that the lower the clipping height, the less digestible the material is. What stage of maturity were these grasses when you cut them? When do you normally get frost or did you get frost in this particular case?

Henry. That clipping in October is solely after frost. All plots got the October clipping after a good frost that killed. This middle clipping height that I keep referring to seems to be about the best height there, 15 cm. July and August were the best for the switchgrass. For big bluestem, July clipping resulted in some of the better stands remaining and the most

yields. These had not had any fertilization at all and we've heard a lot this week about nitrogen. These are still producing fairly good yields on no fertilization at all, no nitrogen. The University of Kentucky has switchgrass in some trials going on right now in mixtures with legumes and also with applied nitrogen so there will be some good things to compare with them.

K. F. O'Connor (New Zealand). Some of you may have seen one slide that I presented yesterday in which I referred to the grassland development transition. You start off with a depleted grassland. You rebuild the fertility of the site and it will be by the most economical way possible of getting the nitrogen recycled in that area. For some time, you are going to go through the process of continuing to have that mass flow of nitrogen recycling, but when it comes down to the fact that you've got to adjust to the variable precipitation that you have through summer and autumn and still do what John Eadie wants us to do, have animal condition there at its best for tupping or mating. Then it becomes of vital importance to know the role of tall grasses in the total feed supply system. Our tall grass Chionochloa, which literally means snow grass, responds very much like your tall grasses. They're adversely affected by clipping height, and the more frequent and the more severe the clipping, the more do they suffer. What interests me a great deal is this question that Dr. Jung raised. We know we've got different ecotypes of Chionochloa within New Zealand. I'm convinced that you've got a tremendous range of ecologic variation in your Andropogons and in the other tall grasses such as Indiangrass and so on in the North American Continent. I suspect that these ecotypes are greatly differentiated by the particular strategies that they have for responding to climatic fluctuation. Now, I mentioned yesterday that Alan Mark found by taking our Chionochloa from the alpine and sub-alpine environments to control climate laboratories at Alberta that our alpine tall grasses were not switched off by a short sharp blast. The equivalent of the Canadian air arriving down here for a fall football game doesn't switch off the plant, but a sustained cold period might. Some ecotypes probably preserved now in your varieties are switched off by only sustained cold; others may be switched off by temporary, but fairly sharp sort of cold.

The second point that I would like to raise is the question of the nutrient cycling with the plant. In animal feeding, we get very concerned about where the protein is. If we think in terms of the internal nitrogen economy of these plants, we start to speculate on when the nutrients move back into sheath tissue for the subsequent spring growth. Now I've asked enough, but we need to know what you now know of the internal physiological strategies of these different ecotypes and different species so that we can start to interpret the results that you're getting with your clipping treatments at different times of the year and at different severities.

Henry. All three of these particular varieties—Blackwell, Kaw and Cheyenne—as you know, came out of the midwest—and whether they are the best ecotypes for this part of the Appalachian Region I refer to, I don't know. They seem to have good seedling vigor. Cutting at various heights didn't have any effect on the protein and the dry matter disappearing or the amount of dry matter the cow takes in but maybe we'll have some ecotypes that will show this. These warm-season grasses are high in proteins, and that's good. The main thing when we started this was to fill in that gap, July, August and parts of September, where the short cool-season grasses are dormant. It may be like Sudan and some of the sorghums—you can just use it as intensively as you'd like and then the cool-season grasses will be coming back a little later.

123.
Tropical Forest Land-Use Evolution in Northern Thailand

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Remote sensing, including conventional photography of earth resources from aircraft and satellite, can generate large quantities of data of significant value to forest and agriculture land-use planning. Multidate aerial photographs provide information on forest and agriculture land-use classification, and their changes. LANDSAT-1 imagery also allows land planners to examine characteristics and the changes of large areas. This paper discusses the role of black and white aerial photographs and satellite imagery to determine forest depletion in the remote area of northern Thailand.

THE STUDY AREA

The study area is located between north latitude 19°12′ and 19°20′ and 98°45′ and 98°59′ east longitude, and includes approximately 290 square km. The vegetation and topography of the area are variable. The vegetation types in the area can be classified into five categories based on the composition of the forest, elevation and slope as follows: hill evergreen forest, dry evergreen forest, mixed deciduous forest with teak, dry dipterocarp forest, and dry dipterocarp forest with pine. The elevation of the study area varies from approximately 400 m to 1 800 m.

Most of northern Thailand is subjected to shifting cultivation. It is estimated that about 2.3 million ha of watershed area have been cleared and burned, mostly by the hill tribes living in the mountainous area of the north (Komkris, 1970). The study area has long been heavily devastated by shifting cultivation. Natural resources destruction information is relatively unavailable, therefore, this investigation was conducted to provide statistical data to support natural resource planning in the future.

GENERAL APPROACH

The historical photo-interpretation was performed on multidate photographs, including LANDSAT-1 imagery of the study area, to classify and map the forest and agricultural land use and to determine changes. The photographs were assembled and interpreted by conventional methods to provide various dates of land-use and change maps.

The research has been undertaken to evaluate the utility of LANDSAT types of systems for providing the data necessary for local and provincial programs. Emphasis is given to their use in forest and agricultural land-use mapping and planning in northern Thailand, and the identification of critical sites, such as shifting cultivation and cultural resource areas.

RESULTS AND DISCUSSION

Forest Depletion

The greatest time interval between dates of the available land use planes was 18 years (1954–1972). Comparison of area measurement for each land use between these two extreme dates provides an initial estimate of evolution of land-use pattern in the study site (Table 1). Total area of each land use on each of four dates revealed more clearly the progressive changes in land use of the site and the recent acceleration of the rate of forest depletion (Fig. 1).

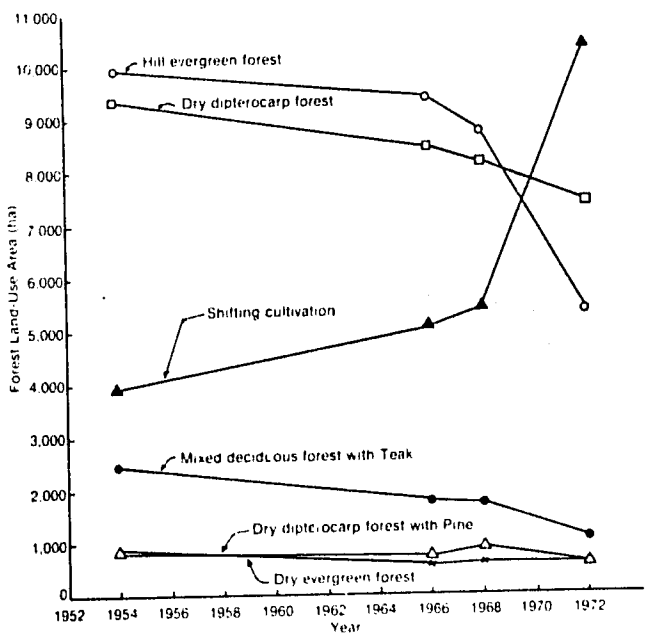


Figure 1. Forest land-use depletion and the concomitant increase in the area of shifting cultivation.

The acceleration rate decrements were evident in all the areas of forest types. The hill evergreen forest appears to have been depleted from 9 909 ha in 1954 to 5 316 ha in 1972 (3.52% per annum); mixed deciduous forest with teak sustained the greatest decrement, from 2 478 ha to 1 073 ha (4.76% per

TABLE 1. Generalized land-use evolution in Nikom Doi Chiang-Dao site between 1954 and 1972

Type of Land Use	Area in sq km 1954	1972	Change	Change in Percentage (18 yrs)	Change in Percentage (Yearly)
Hill evergreen forest	99.09	53.16	−45.93	−46	−3.52
Mixed deciduous forest with teak	24.78	10.73	−14.05	−57	−4.76
Dry dipterocarp forest	93.60	73.89	−19.71	−21	−1.32
Dry dipterocarp forest with pine	8.24	5.32	−2.92	−35	−2.46
Dry evergreen forest	8.80	5.42	−3.38	−38	−2.72
Subtotal of forest types	234.51	148.52	−85.99	−37	2.57
Swidden areas	39.51	103.09	63.58	+161	+5.47
Irrigated rice fields	15.02	24.70	9.68	+64	+2.80
Tea plantations	3.50	16.38	12.88	+368	+8.95
Teak plantations	0.00	0.43	0.43	—	—
Total	292.54	293.12	+0.58*		

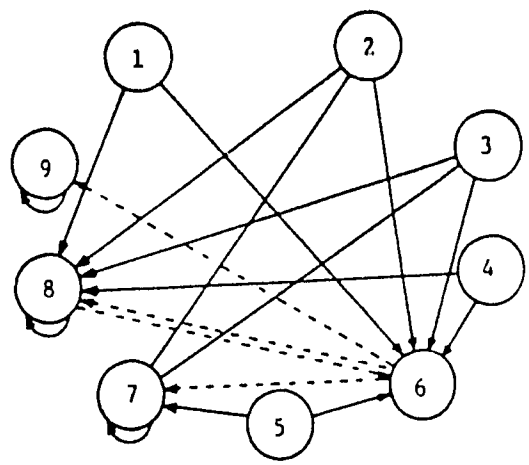
*Discrepancy of the total land use area is due to coding errors along the study area boundary.

annum); dry dipterocarp forest decreased from 9 360 ha to 7 389 ha (1.32% per annum); dry dipterocarp forest with pine from 824 ha to 532 ha (2.46% per annum); and dry evergreen forest from 880 ha to 542 ha (2.72% per annum). The depletion appeared most significant in the hill evergreen forest and mixed deciduous forest with teak because of their cool climate and fertile soils and the presence of commercial timber, respectively.

A concomitant increase took place in other competing land uses. Swidden areas, irrigated rice fields, and tea plantation increased from 3 951, 1 502 and 350 ha in 1954 to 10 309, 2 470, 1 638 ha, respectively, in 1972 (5.47%, 2.80% and 8.95% per annum). A total of 8 599 ha of forestland had disappeared between 1954 and 1972, or about 37% of the forest area present in 1954, an average annual depletion rate of 2.57%. Teak plantations were first established in 1968. By 1972 the area of the plantations was 43 ha.

Tropical Forest Land-Use Evolution

The Markov Chain model was developed to simulate land-use evolution. The 9 by 9 element (for all nine possible land uses) probability transition matrix, P = (Pjk), multiplied by the stochastic row vector, V = (Vj), yielded a simulated area of each land use at each iteration. The projection will be performed for a century but the validity of the model is limited within some period. The complete models of the future of each of the nine individual land uses of the site based on the 1968/1972 data planes



= forest type.

= steady or stable state.

→ = a pathway of possible changes. The head of the arrow indicates the direction of event.

--→ = occurrence of less common sequences.

Figure 2. Forest transformational diagram of the Markov model of land-use evolution. The numbers inside the circles present the index of each forest ecotype as coded earlier for each 1-ha cell on four dates. 1 = hill evergreen forest type; 2 = mixed deciduous forest type with teak; 3 = dry dipterocarp forest; 4 = dry dipterocarp forest type with pine; 5 = dry evergreen forest; 6 = swidden area; 7 = irrigated rice field; 8 = tea plantation; 9 = teak plantation.

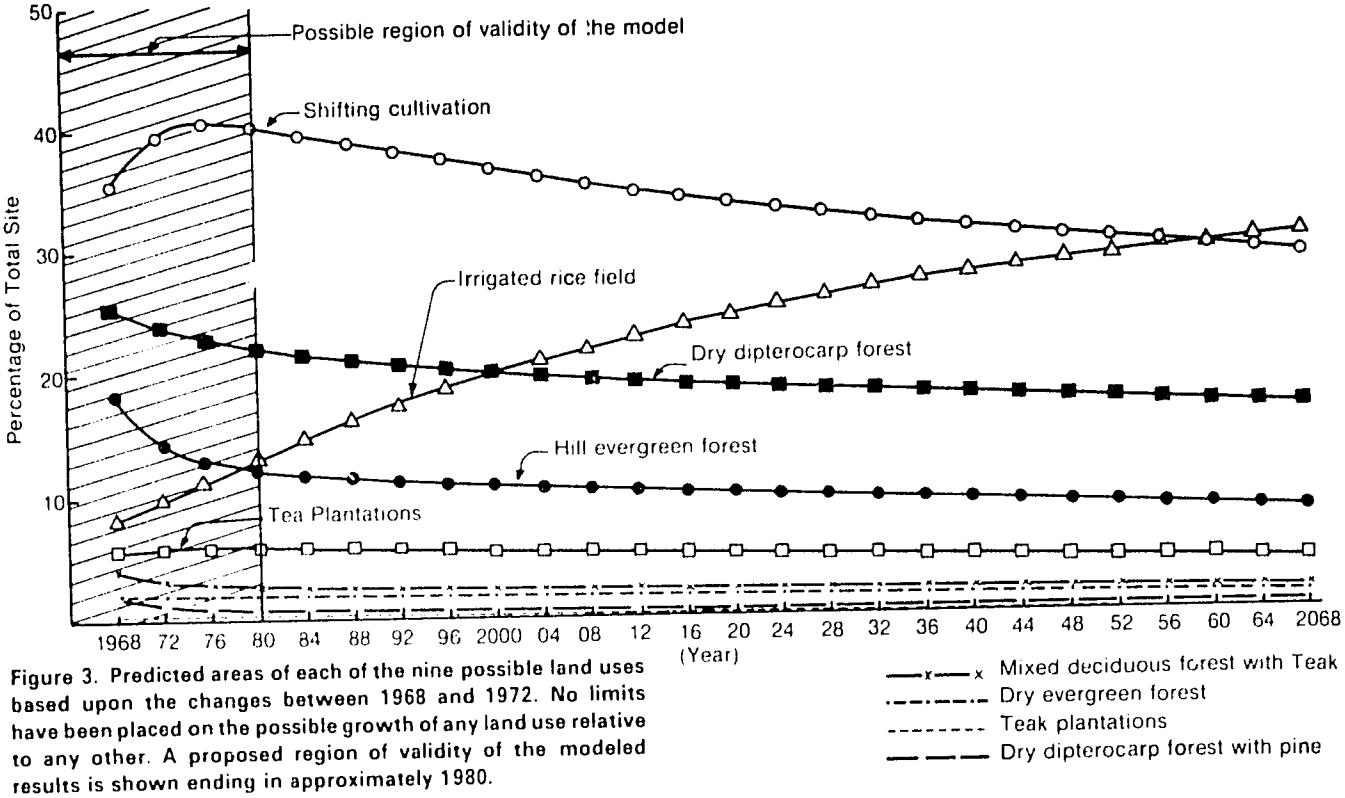


Figure 3. Predicted areas of each of the nine possible land uses based upon the changes between 1968 and 1972. No limits have been placed on the possible growth of any land use relative to any other. A proposed region of validity of the modeled results is shown ending in approximately 1980.

clearly show the limitation of attempting to interpret long-term future trends from such models. The transformational diagram of land-use evolution can be expressed in terms of a systematic diagram (Fig. 2). The projection of the trends in land-use evolution is illustrated in Fig. 3.

Sensitivity Analysis

A general approach to preparing a spatial land-use model treats the past, current, or change in the land use of a cell (e.g., one ha) as the dependent variable and other characteristics; elevation, slope, and aspect, as the independent variable. The examples show only the distribution histograms (sensitivity) of 1972 swidden area versus elevation, slope, and aspect, respectively, but similar histograms were produced for all land use and dates.

The example histogram for the sensitivity of shifting cultivation versus elevation (Fig. 4) illustrated that the 1972 shifting cultivation was at an average elevation of 1082 m with one standard deviation (±σ) ranging from 442 to 1738 m. A second histogram (Fig. 5) illustrated that shifting cultivation was practiced at the average slope 31% with ±σ range from flat to a slope of 70%. The histogram of swidden areas as a function of aspect (Fig. 6) showed that slope aspect has very little role in determining shifting cultivation practice, probably because the

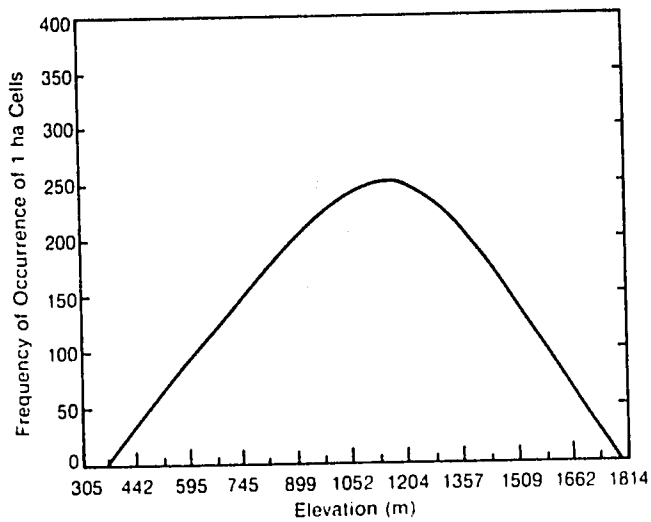


Figure 4. Distribution of 1972 swidden areas vs elevation.

energy balance of surfaces with respect to aspect are approximately equal in tropical regions.

Value of ERTS Imagery

We found that MSS band 5 is the best single band for first and second order classification of forest and agriculture land use. However, MSS band 7 was found to have a good contrast in land and water discrimination. Five land-use categories in the study

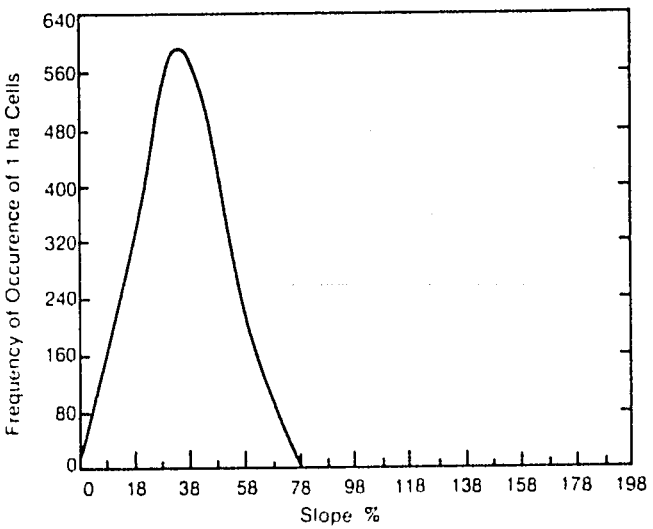


Figure 5. Distribution of 1972 swidden areas vs slope.

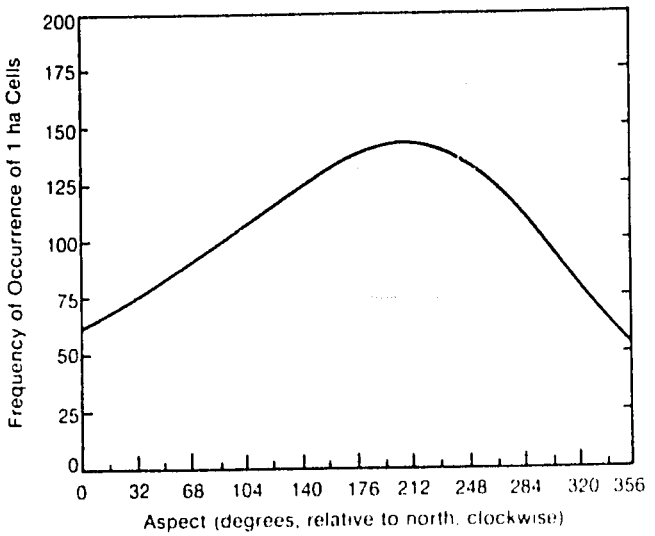


Figure 6. Distribution of 1972 swidden areas vs aspect.

area were identified on MSS band 5 and four on band 7 at 1:250 000 scale. Color IR composite photographs, which are a combination of bands 4, 5, and 7 at 1:250 000 scale, yielded additional land-use classes which could not be identified at all on either of the black and white images. Shifting cultivation can be distinguished on both black and white and color composite images.

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124.
Honey Production on Reclaimed Strip Mine Spoil

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Currently an estimated 405 000 ha (one million acres) of land has been disturbed by strip mining in the Appalachian region (Grim and Flynn, 1976). Many of the plants being used to stabilize these lands represent a potential nectar source for the production of honey and bees wax.

No formal research has been conducted to measure the honey productivity potential of reclaimed strip mine spoil. However, several progressive beekeepers have recognized and have begun to utilize these nectar sources (*Floyd County Times*, 1976).

Approximately 88 775 160 kg of honey were produced in the United States in 1975 and sold at an average wholesale price of about one dollar per kg. However, an additional 18 160 000 kg of honey were imported, illustrating the existence of a market for increased honey production (*Honey Production*, January 20, 1976). This increase in production can very possibly come from utilizing the nectar sources on strip mine spoil.

A study on potential honey production on strip mine spoil was initiated in the spring of 1976 with the following main objectives: (1) to determine the number of kg of honey produced from nectar sources grown on strip mine spoil; and (2) to identify hive management techniques that may be unique on strip mine spoil.

MATERIALS AND METHODS

On May 10, 1976, 40 newly established colonies of honey bees (*Apis mellifera* L.) were placed on reclaimed strip mine spoil on the Vouge Mine owned

by Peabody Coal Company in Muhlenberg County, Kentucky (37.20 N 87.30 W).

The plant cover in this area was seeded in 1974. The following vegetative species were present when the colonies were located on the reclaimed area: alfalfa, (*Medicago sativa* L.); white dutch clover, (*Trifolium repens* L.); yellow sweetclover, (*Melilotus officinalis*); birdsfoot trefoil, (*Lotus corniculatus* L.); red clover, (*Trifolium pratense* L.); sericea lespedeza, (*Lespedeza cuneata*) and tall fescue, (*Festuca arundinacea* Schreb). The following tree species were within 750 meters of the apiary: black locust, (*Robinia pseudoacacia*); eastern cottonwood, (*Populus deltoides*); yellow-poplar, (*Liriodendron tulipifera*); green ash, (*Fraxinus pennsylvanica*); sweetgum, (*Liquidambar styraciflua*) and autumn olive, (*Elaeagnus umbellata*). In addition, many volunteer wildflowers were observed on the site. The spoil reaction of the area ranged from pH 5.8 to 6.0. Visual estimation of the percentage of ground cover ranged from approximately 70% to 100%.

The colonies were located in the middle of 769.50 ha (1 900 acres) of reclaimed spoil on a gentle slope with a southeast aspect. No shade was provided for the colonies; water was available from a large impoundment about 75 m from the bee yard. The mean pH of the water was 7.5. The hives were mounted on railroad ties which were brought to the site. The vegetation in front of the hive entrances was kept clipped. Each colony was examined and manipulated at regular intervals to insure proper hive management. Colony strength was variable due to a high mortality rate during shipment.

RESULTS AND CONCLUSIONS

Honey was removed and extracted from 13 of the 40 colonies on July 17, 1976. A total of 119 shallow super frames were removed which yielded 249.0 kg of extracted honey. This represents an average of 19.1 kg of honey produced per productive colony with a range of 3.8 to 38.5 kg per colony. Honey was harvested only from those hives that had a surplus of honey (those that had full frames of sealed comb in the first shallow super above the brood chamber). All but two of the remaining 27 colonies that were not harvested on July 17, 1976, had completely filled their brood chambers with nectar, pollen and brood, and had started drawing out comb in the first shallow super. The two remaining had only partially filled their brood chambers.

DISCUSSION

Level of Productivity

Strip mine spoil revegetated with a high percentage of nectar-producing plants has a high honey productivity potential. In 1975, the average production per colony in the United States was 21.4 kg of honey (*Honey Production*, January 16, 1976). Honey production in this study was only 2.3 kg less per productive hive than this figure. This yield is significant for two reasons: (1) the honey was removed at mid-season and much more can be expected to be produced by the end of the summer, and (2) colonies were newly established. The high honey production can be attributed to a better seasonal distribution of nectar flows from the high concentrations of alfalfa and yellow sweetclover on the revegetated spoil. On more acid spoil, these findings are not likely to be repeated.

A better utilization of the honey-producing potential of reclaimed strip mine spoil would have several beneficial side effects. Increased honey production would provide more jobs and another source of income for many people. Naturally, commercial honey producers could most efficiently tap this resource because of their experience and more efficient equipment. However, the resource could also serve as an income source for amateur and part-time beekeepers, handicapped persons, and for retirees who approach beekeeping as a hobby.

Another obvious advantage to managing honey bee colonies on strip mine spoil is plant pollination. While gathering nectar, the bees also pollinate the flowers, thus increasing seed set. Where strip mine vegetation is not utilized for grazing or for forage, this increased seed set could result in a thickening of the stand and a more rapid achievement of the percentage of vegetative ground cover required by reclamation laws.

HIVE MANAGEMENT TECHNIQUES

For the most part, honey bee colony management on spoil material would parallel management techniques utilized on undisturbed land. However, several unique situations may be encountered on strip mines which require four special management techniques: security, shade, water, and crop management practices that would maximize honey flow.

Security

Unfortunately, security is a universal problem on large mine sites. To minimize vandalism or theft, the hives should be located in an area that is naturally hidden from view from access roads, water impoundments, etc. Examples of good hiding places would be in natural drains or behind swales, in tall grass, or in a grove of trees on the periphery of a mined area. Road access to the apiary should be controlled by a strong gate. The mine superintendent should be advised of the hives and asked to keep an eye on them.

Shade

Shade sources may have to be built for the bee colonies since most spoil material has no source of shade. If the temperature inside the hive is over

34 C, the worker bees will spend their time collecting water and fanning the hive in order to cool it (Root, 1974). A simple lath structure mounted on posts over the hives would suffice as a shade source.

Water

The apiary must be placed near a fresh, pure water source. Acid mine drainage which is frequently found on strip mine sites could prove detrimental to the colonies. If no suitable water source is present within one-half mile, it must be provided. It is best to provide water that does not stand in a container with a still surface but rather drips from a container onto a sloping board or trough where it can be collected by the bees as it flows along (Dadant and Sons, 1975).

Crop Management Practices

Utilization of crop management practices that will extend the annual honey flow is needed to maximize honey production. These practices might include mowing reclaimed areas to promote regrowth of the grasses and legumes. Mowing would also shatter seed pods which would, in effect, result in reseeding.

NECTAR-PRODUCING VEGETATION

Currently, the authors estimate that each ha of reclaimed strip mine spoil will support two to four colonies of bees. When pollination is the only objective, more may be required depending upon the vegetation needing pollination.

Alfalfa has become a very important legume on less acid spoil materials. About four or five colonies per one-half ha are frequently used for this crop, although experiments show that much more seed can be produced if more colonies are used. It is interesting to note that little nectar is produced by alfalfa flowers in June or July on the first cutting: it is from the second and third cuttings, in late July, August, and early September, that the most nectar is produced. Alfalfa honey is light in color and mild in flavor (Dadant and Sons, 1975).

White, crimson, and alsike clovers are by far America's most important honey plants and are widely planted on spoil material. They start to flower sometime between mid or late June and continue to yield nectar through about the first of August. It is recommended that one to two colonies be used per one-half ha for red clover (depending on the number of bumblebees in the area) and one to three colonies per one-half ha for the other clovers (Dadant and Sons, 1975).

White and yellow sweetclover have also been seeded on spoil material, and bees are necessary for the pollination of both. Like the other clovers, they flower in mid to late June and require one or more colonies per one-half ha (Dadant and Sons, 1975).

Only one colony per one-half ha has been recommended for perennial lespedeza but no recommendations have been made for the use of insect pollinators on the annual types (Dadant and Sons, 1975).

Both hairyvetch and crownvetch can benefit greatly from honeybee pollination. Seed production is increased by using one colony per one-half ha (Dadant and Sons, 1975).

Buckwheat is frequently planted on spoil. It may be sown any time up to the first week of July and produces nectar usually in about six weeks. However, the flowers secrete nectar only in the morning, toward noon the flow lessens, and ceases entirely during the afternoon; but flow begins again vigorously the next morning. Pure buckwheat honey is coal black and commands a high price. One colony per one-half ha is recommended (Dadant and Sons, 1975).

Black locust trees are known as the "King Tree Species" on spoil material and are also very important honey plants. The locust flowers occur in dense clusters in April, May, and early June, before the hives have had a chance to build up to maximum strength. The honey is water white, with a mild flavor. Some beekeepers have been known to place fresh supers in the hive just as locust comes into bloom and remove them at the end of the flowering season (Root, 1974).

The yellow poplar or tulip tree is also widely planted on spoil material. It blooms in late April, May, and early June. The honey obtained is bright amber when new but becomes redder and very thick with age (Lovell, 1974).

Strip mining is an enormous industry in the United States. Since many of the plants being used to stabilize reclaimed lands represent a potential nectar source, honey production could well become a new end-land use and an important spinoff of coal production.

ACKNOWLEDGMENTS

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125.
Use of a Mathematical Model to Evaluate the Hydrological Effects of Land-Use Change

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Watershed managers are interested in the response of streamflow to land-use change. This response could be an increase in streamflow volumes, higher storm-flow peaks, or an increased proportion of stormflow to baseflow after the land-use change. In this paper, watershed response is defined as that component of annual streamflow volume attributable to a land-use change. We are interested in both the magnitude and variation of watershed response.

Douglass and Swank (1975) showed that the land-use change, watershed treatment, and the aspect of the watershed caused significant variation in watershed response. Lynch and Sopper (1970), Hornbeck *et al.* (1970), Hibbert (1971), and Rich and Thompson (1974) showed that rainfall could also be an important source of variation. In general, watershed response is accentuated by higher rainfall.

The magnitude of watershed response will determine the effectiveness of land use as an option for increasing the yield of a water supply system. If the response is considerably greater in wet years than in dry ones, larger reservoirs will be needed to regulate the responses, i.e., to hold large responses in wet years for use in dry ones. The magnitude of watershed response to a particular land-use change is usually evaluated using experimental watersheds. Inability to control rainfall at the time of implementing the land-use change on such watersheds can make interpretation of the results difficult. In this paper, we describe a technique for evaluating watershed response under a wide range of rainfall amounts.

The technique involves calibrating a mathematical model on data from several experimental watersheds with different land uses. The next stage is to look for likely sources of variation in watershed response. In the study presented here, rainfall before and after implementation of the land-use change, and the land-use changes themselves, were considered as the principal sources of variation in response. A factorial experiment was set up with three levels of antecedent and three levels of post-treatment rainfall so that five land use options could be compared under each of nine climatic sequences. The variation in watershed response attributed to rainfall and treatments was then studied.

The technique relies on the model's ability to describe the hydrologic cycle. Although the ability of the present generation of models to do this is debatable, watershed managers must make decisions on the basis of the present levels of technology. Modeling, despite its shortcomings, is the best alternative available for evaluating watershed response. The technique of selecting sequences of climate with particular attributes and organizing them in an ordered statistical experiment will be more widely used as mathematical models of the hydrologic cycle improve.

MODEL AND WATERSHED USED IN SIMULATION STUDY

The mathematical model of the hydrological cycle developed by the U.S. Department of Agriculture Hydrograph Laboratory (Holtan *et al.*, 1975) was used. Langford and McGuinness (1976) describe in detail the calibration and testing of the model on data from the North Appalachian Experimental Watershed near Coshocton, Ohio.

Watershed No. 172, the principal source of data, is described by Harrold *et al.* (1962). In 1938–39, pines were planted on 11.7 ha of badly eroded land

of Watershed 172 with 5.9 ha of residual hardwoods left undisturbed. Statistical studies showed that, after an initial decrease, streamflow stabilized. There are no time trends in streamflow between 1950 and 1965. The eight years between 1950 and 1957 were used to calibrate the model, and the years between 1958 and 1965 to test it. Parameters for grass cover are evaluated from measurements on a weighing lysimeter and an adjacent watershed. Watershed behavior using parameters for grass, pines, and hardwood forest are compared for a 16-year period of record. Data describing watershed response to forest conversion given by Swank and Douglass (1975) and Hibbert (1969) are used in the assessment of model performance.

Bedrock of Watershed No. 172 consists of cyclic deposits of sandstone, shale, limestone, coal, and clay of the Pennsylvanian system. Residual Muskingum-Keene soils are well-drained silt loams. The highest and lowest points in the watershed are 393 and 306 m, respectively; slopes average 23%. Precipitation averages about 1000 mm yearly and average annual temperature is about 11 C.

RAINFALL SEQUENCES

In setting up the land-use modeling experiment from the 32-year historical record, three measured periods of wet, average, and dry rainfall were selected to represent antecedent conditions. These were combined with three measured wet, average, and dry periods representing post-treatment rainfall to form nine artificial sequences. Table 1 shows the measured rainfall totals for the three antecedent and three post-treatment sequences.

May–April water years are the basic unit of time because they divide neatly into May–October growing and November–April dormant seasons. Since the USDA Hydrograph Laboratory (USDAHL) model uses calendar years of data, model calculations over a four-year period are used to generate the three water years of data used in the statistical analyses.

The watershed condition as represented by the mixed hardwood and pine forest on Watershed No. 172 during the 1950–57 calibration period is used as the standard for calculating streamflow changes. Streamflow is computed using land-use parameters appropriate for this period under the nine climatic sequences. The calculations are then repeated, but with the land-use parameters changed at the end of the antecedent period to reflect the synthetic land-use changes described below. Differences in streamflow during the post-treatment periods represent the simulated watershed responses.

LAND-USE OPTIONS

Beside the assumed range in rainfall amounts, five synthetic land-use options were used in designing the statistical experiment. The following options were chosen to cover a range of practical alternatives for Watershed No. 172.

1. The whole watershed was assumed to have a deep-rooted (1.8 m) grass cover. Crop parameters derived for the bromegrass-alfalfa mixture in the lysimeter were used.
2. The whole watershed was assumed to have shallow-rooted grass cover. Crop parameters were the same as option 1, except rooting depth was 0.46 m.
3. The pine areas of forest, comprising zones 2 and 3 (Fig. 1), were assumed to have been replaced by deep-rooted grass. The crop parameters for the grass are the same as for option 1.
4. The pine areas (zones 2 and 3) were assumed to have been replaced by pine seedlings. The crop parameters derived from the first year of modeling of the 1940–49 reforestation were used for zones 2 and 3.

TABLE 1. Rainfall selected for antecedent and post-treatment periods

	Antecedent Periods		Post-treatment Periods	
Rainfall Level	Water Years	Rainfall Over the Two Water Years	Water Years	Rainfall Over Water Years
		mm		mm
Wet	1957–58 1958–59	2 037	1950–51	1 156
Average	1963–64 1964–65	1 627	1944–45	913
Dry	1952–53 1953–54	1 484	1953–54	709

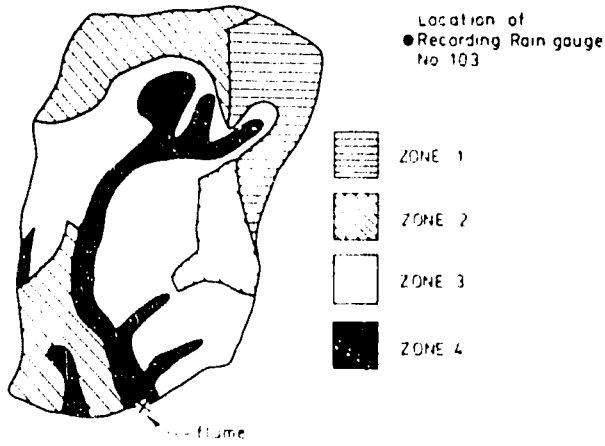

Figure 1. Zone map of Watershed No. 172.

5. The watershed was assumed to be converted to a recreational area. Crop parameters for the roads and paved parking areas are selected so that infiltration and evapotranspiration were zero. A total of 9% of the watershed was assumed impervious.

VARIATION OF WATERSHED RESPONSE WITH RAINFALL

Table 2 shows the post-treatment water year streamflows simulated by the model for the mixed hardwood and pine forest over the nine sequences of rainfall, as well as streamflow for the five land-use options. Streamflows from the mixed hardwood and pine forest illustrate the effect of the antecedent and post-treatment rainfall. When the post-treatment rainfall decreases from wet to dry after wet antecedent rainfall, the streamflow decreases markedly from 490 to 103 mm. Antecedent rainfall had a discernible but much smaller effect. Simulated streamflow decreases from 490 to 482 mm as antecedent rainfall decreases from wet to dry under high post-treatment rainfall.

The more important effect of post-treatment rainfall, as compared with antecedent rainfall, was expected. The watershed is small with a relatively low capacity for storing ground water, and the soil mantle usually reaches field capacity at the end of the dormant season, even during dry years. Carry-over of soil moisture deficits from one year to the next is not an important feature of Watershed No. 172.

After an initial inspection, antecedent rainfall could have been neglected. However, it was included in the analyses because one purpose of the study was to develop a technique that can be applied to other watersheds. In watersheds with greater capacity for storing groundwater, and where carry-over of soil moisture deficits from one year to another are important, antecedent conditions would have a greater influence.

The effects of rainfall on watershed response are discussed only for land-use option 1—conversion of the mixed forest to deep-rooted grass over the whole watershed. Trends in watershed response for the other four management options were similar. The simulated watershed response to option 1 decreased significantly as post-treatment rainfall decreased and only slightly as antecedent rainfall decreased. For example, for wet antecedent rainfall, the response decreased from 125 to 46 mm as the post-treatment rainfall decreased from wet to dry. Table 3 shows that the relative simulated watershed response to land-use options is greater for dry than for wet post-treatment rainfall when antecedent rainfall is average.

Figure 2 shows the simulated evapotranspiration and interception for the mixed hardwood and pine forest and deep-rooted grass over the May to October growing season under high, average, and low post-treatment rainfall, i.e., gross rainfall minus canopy interception. The USDAHL model considered the interception of rainfall by grass as small, and all interception for grass is included with evapotranspiration. We altered the model to subtract forest interception from gross rainfall, so only net rainfall is subject to infiltration. When calculating evapotranspiration, the soil moisture depletion function of the model progressively decreases the evapotranspiration rate as the soil dries. Under wet conditions, neither the forest nor the grass is limited for water, and calculated evapotranspiration proceeds at or near the potential rate. The difference in consumptive use is essentially the interception difference.

TABLE 2. Model-simulated streamflow and responses to treatment (mm) for five management options under nine rainfall sequences

Rainfall Sequence		Mixed Hardwood & Pine Forest	Synthetic Treatments: Option 1 Deep-rooted Grass		Option 2 Shallow-rooted Grass		Option 3 Pine to Grass		Option 4 Pines Cut & Replanted		Option 5 Recreation Use	
Antecedent	Post-treatment	Streamflow	Streamflow	Response	Streamflow	Response	Streamflow	Response	Streamflow	Response	Streamflow	Response
Wet	Wet	490	615	125	639	149	602	112	705	215	528	38
	Average	257	318	61	357	100	327	70	427	170	285	28
	Dry	103	149	46	195	92	158	55	261	158	133	30
Average	Wet	483	607	124	632	149	594	111	699	216	522	39
	Average	249	308	59	347	98	317	68	420	171	277	28
	Dry	96	140	44	186	90	149	53	254	158	125	29
Dry	Wet	482	603	121	628	146	591	109	700	218	520	38
	Average	247	306	59	344	97	316	69	421	174	276	29
	Dry	94	134	40	182	88	146	52	255	161	124	30

TABLE 3. Relative simulated watershed responses to land-use change for average antecedent rainfall

Post-treatment Rainfall	Streamflow Under Mixed Hardwood and Pine Forest	Land-use Options 1	2	3	4	5
	mm			%		
Wet	483	26	31	23	45	8
Average	249	24	39	26	69	11
Dry	96	46	94	56	166	31

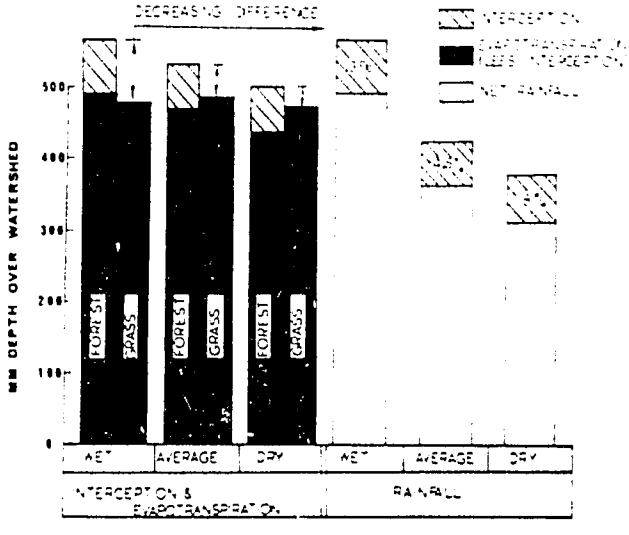

Figure 2. Effect of decreasing rainfall during the growing season.

As rainfall decreases during the growing season, the difference between gross and net rainfall becomes more important. The soil moisture depletion function suppresses transpiration of the forest more than that of grass, because the grass receives more rain water and, consequently, soil moisture levels are higher. Under dry conditions, differences in water consumption of different plant covers are suppressed, because supply of water to the plants is the limiting factor for all plant covers.

ANALYSIS OF VARIANCE

The hydrologic effects of the land-use options described earlier are examined by an analysis of variance. Total streamflow, surface runoff, subsurface runoff, evapotranspiration, and interception are all analyzed by this method. Langford and McGuinness (1976) describe the statistical methods and results in detail.

Average annual water balances of the land uses are compared in Table 4. Clear cutting of the pine forest in zones 2 and 3 (Fig. 1) followed by erosion and planting of pine seedlings (option 4) shows the largest increase in average streamflow. Zones 2 and 3 effectively represent the area on Watershed 172 planted to pines in 1939 so that this treatment put the watershed back in the same condition as in 1940. It was the only land use that showed significantly lower evapotranspiration (excluding interception), which supports the conclusion that increased interception of the growing pine forest is not sufficient to explain the change in streamflow. Increased transpiration is also important. In addition, this land use is the only one to show a significant increase in surface runoff. These conclusions support the earlier work of Harrold *et al.* (1962) who conclude that infiltration is increased after establishment of the pine forest, but that increased interception and transpiration reduce streamflow.

The erosion and subsequent deterioration in water quality rule out option 4 as a practical management alternative for increasing streamflow. Option 2, complete removal of all the forest followed by planting of shallow-rooted grass, and option 3, the removal of forest in zones 2 and 3 (essentially all the pine forest) followed by establishment of a deep-rooted grass, show the next largest increases in average streamflow. Option 3 has the advantage of giving the watershed a multi-purpose role, a residual hardwood forest plus high quality pasture and water, and appears to be the best management alternative.

The average increase in streamflow is not the only criterion which should be used for comparing management options. The dry period flow is also important. Table 3 shows that option 2 increases annual flows in a dry year by 94%, whereas option 3 increases flow by 56% under the same conditions. Increases in dry period flows are a better indication of benefits to a water supply system. If water yield has a higher priority than productivity of the land, then shallow-rooted grass is a viable alternative, providing it is capable of preventing erosion.

DISCUSSION AND CONCLUSIONS

The hydrologic cycle of hilly terrain is judged to be sensitive to land-use change on the basis of hydrologic model simulations. Managers of such land should, therefore, be aware of implications of any change in land use. In this simulation study, watershed responses to five assumed land-use options are compared under nine rainfall sequences. Individual components of water balance are analyzed separately and significant differences among options are found in simulated average annual streamflow, surface runoff, and evapotranspiration. Benefits in terms of increased streamflow and the significance of these increases are evaluated in the modeling so that rational management decisions can be made.

The variation in watershed response is also important. The absolute watershed response decreases with

TABLE 4. Effect of land-use on average annual water balance components, (mm)

Option No.	Watershed Cover and Synthetic Treatments	Evapo-transpiration (Including Interception)	Interception	Streamflow	Subsurface Flow	Surface Runoff
Check	Mixed hardwood and pine forest (original condition)	647 a	113 a	278 a	262 a	15 a
1	Whole watershed planted to deep-rooted grass	573 ab	— b	353 bc	337 bc	16 a
2	Whole watershed planted to shallow-rooted grass	536 bd	— b	390 cd	369 c	21a
3	Zones 2 and 3 planted to deep-rooted grass	573 ab	25 c	356 bc	339 bc	17 a
4	Zones 2 and 3 allowed to erode and replanted to pines	464 d	52 d	461 d	357 bc	103 b
5	Recreational use	615 ab	104 a	310 ab	291 ab	19 a

Means within a column followed by the same letter do not differ significantly at the 5% level according to Duncan's multiple range test.

decreasing rainfall; the relative responses are much greater under dry rainfall conditions. Both these factors are important in evaluating the potential benefits of vegetation manipulation to a water supply system. Dry period flows are a better indication than average flows of the reliable yield of a water supply system so that potential benefits are relatively greater than indicated by the average response. The simulated dry period response of 31% gained from installing a relatively small proportion of paved area (9%) is particularly interesting. The larger responses in wet years from all land-use management options can be utilized if extra regulating storage is installed in a water supply system.

The comparison of several land-use options by matching climate sequences with particular attributes in an ordered statistical experiment demonstrates the advantages of an approach using a model supported by statistical methods. Further, mathematical modeling of the whole hydrologic cycle provides a useful framework for quantitative assessment of the many hydrologic implications of a management decision, rather than a more detailed consideration of only one aspect. Despite the limitations of present models, they provide a most promising approach to the solution of land management problems.

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DISCUSSION

C. Sperow (West Virginia, USA). You didn't mention on your tall and short grasses, deep-rooted or shallow-rooted grasses, what the management on these were. Were they harvested or just allowed to grow? Also, did you measure sediment yields?

Langford. As far as I'm aware the grasses weren't harvested on the lysimeters. Both of them were fertilized over a period of about ten years. I didn't measure surface runoff of silt, but I believe the swards, both of them, had a fairly complete ground covering.

Sperow. But I was speaking of your plots.

Langford. The first sequence—we have measured sediment, yes, and it just about doubled under that clear cutting arrangement, but the sediment yields were very low in absolute terms anyway, extremely low. Doubling something small isn't particularly important, and, in fact, we found that most of our sediment can be attributed to the roads rather than the clear cutting or the regeneration activities.

126.
Federal-State Cooperation Encourages Multiple-Use Management of Private Forestland in Northeastern United States

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Nearly all the papers presented at this Symposium have been concerned with production of agricultural crops on hill lands. Forestry has scarcely been mentioned, except as an impediment to conversion of hill land to pasture and food production. This is understandable in view of the increasing population of the world, particularly in the developing nations where hill lands represent the only considerable area for agricultural expansion.

In the United States, however, our farm and forest lands are relatively stable, although in recent years considerable acreages have been cleared of forests in the South for row crops in the Mississippi Valley lowlands and for pasture on the hilly uplands. In other major geographical sections, forestland has increased somewhat, especially in the North Central and Northeastern regions through continued but slowing abandonment of marginal farms.

I will give a brief outline of the size and character of our northeastern forests and the demographic, economic, and physical conditions under which they are growing, describe the organization of the federal forestry effort in encouraging multiple use of forest lands, and outline some of the methods of accomplishing this goal.

AREA CHARACTERISTICS

This area is bordered on the south by a line running west from the Atlantic Coast through Washington, D.C., to West Virginia, on the east by the Atlantic Ocean, and on the north by Lakes Erie and Ontario and the Canadian border. The institutional arrangements for delivering federal forestry assistance in the 12 states in this area are essentially similar to those in the other 38 states.

This area (Table 1) includes some of our most populous states—New York, Massachusetts, Pennsylvania and Maryland. These 12 states, covering 5% of the nation's land, support 51 million people, about one-fourth of the total U.S. population. Such great seaboard cities as New York, Boston, Providence, Philadelphia and Washington, as well as important inland ones such as Buffalo, Pittsburgh, Rochester, Springfield, Albany and Syracuse are centers of commerce and finance, light and heavy industry, education, transportation and government.

Yet, despite this concentration of human activity, 68% of the land is covered with forests, the highest proportion of any major U.S. land area. At the time of settlement, the forest had to be laboriously cleared for establishment of farms, but forests also provided an important resource for local use and export trade with Europe. The many species of the hardwood and coniferous trees provided fuel, building materials for dwellings, factories, furniture, tools, ships and vehicles, as well as nuts, fruits and acorns for human beings and domestic animals.

At the peak of farming activity in the mid 1800's, as much as 80% of the land area of the New England states had been cleared for farms; but, with the

TABLE 1. Population, land area, and forestry statistics for 12 northeastern states

State	Population[a]	Total[b] Area	Forest Area Total	Forest Area All Land	Private Nonindustrial Forest Total	Private Nonindustrial Forest All Forest	Total Wood Harvest
	Millions	ha 10^3	ha 10^3	%	ha 10^3	%	cm 10^3
Connecticut	3.03	1 261	885	70	814	92	241
Delaware	.55	513	158	31	142	96	337
Maine	.99	8 012	7 183	90	3 369	47	11 574
Maryland	3.92	2 577	1 198	46	1 049	87	2 141
Massachusetts	5.69	2 029	1 424	70	1 146	80	886
New Hampshire	.74	2 339	2 077	89	1 429	69	1 713
New Jersey	7.17	1 951	997	51	848	85	348
New York	18.33	12 398	7 032	57	5 024	71	3 254
Pennsylvania	11.79	11 611	7 216	62	5 448	75	6 564
Rhode Island	.95	272	175	64	163	93	68
Vermont	.44	2 402	1 777	74	1 327	75	1 444
West Virginia	1.74	6 237	4 926	79	4 255	86	4 395
Total	51.34	51 602	35 048	68	25 014	71	32 965

[a]U.S. Census Bureau, 1971.
[b]U.S. Forest Service, 1973, for this and other columns.

opening of the more fertile, easily farmed level lands of the Midwest, the poorer farms on the hills were abandoned and reverted naturally to forest.

Thus, by 1970, the more mountainous and less favorably situated states such as Maine, New Hampshire, Vermont, Connecticut and West Virginia were 70 to 90% forested (Table 1). Although farm abandonment continues, spreading of residential, recreational, and industrial activities out of the population centers has in part offset return of farmland to forest.

The forest types of this extensive area, which has a latitudinal width of eight degrees (37 to 45° N) and elevational changes from sea level to 1 900 m, are varied. They range from southern pines in Delaware and Maryland to red spruce and balsam firs in northern New York and New England, from the oak-hickory forests of the lower elevations and southern sectors to the northern hardwood types of sugar maple, yellow birch and beech.

More than 30 species are commercially important, including fine hardwoods for furniture and panelling; lower valued hardwoods and pine, spruce and fir for pulpwood; and other species for construction lumber. The harvest of wood in 1970 (Table 1) was estimated at 33 million cubic m, considerably less than the growth.

Although these forests are growing on hilly lands, many of which have thin rocky soils of relatively low fertility, they are well adapted to these conditions and are generally productive. Much is known about their management. Precipitation is adequate, ranging from 900 to 1 200 mm, well distributed throughout the year. Severe droughts and extensive forest fires are uncommon.

Because the northeastern forests are so accessible to great population and industrial centers, they have a high potential for multiple use. The major outdoor recreational areas include the Pocono Mountains of Pennsylvania, the Catskill and Adirondack mountains of New York, the White, Green and Berkshire mountains of New England, and the Allegheny mountains of West Virginia, Maryland and Pennsylvania—all hilly to mountainous heavily wooded areas. A large army of bird and deer hunters invade them in the fall. Winter sports areas are found at the higher elevations and in northerly areas. Their scenic beauty, lakes, and cool climates attract summer vacationers. These wooded areas are also watersheds where domestic and industrial water supplies originate.

These forests, because of past abuse through fire and mismanagement, are producing well below their potential. This is well documented for wood production, because many of the highly defective young trees will never produce quality products. Much land can be improved for wildlife habitat by proven techniques of vegetation manipulation. Foresters are learning more about the esthetic and recreational appeal of the forest—what people wish to see and do in the forest environment. Eventually we will understand what constitutes an attractive forest landscape for different segments of the using public and will direct our efforts towards providing these different landscape types.

OWNERSHIP PATTERNS

Unfortunately, the pattern of land ownership and the motive of the owners make application of multiple-use management complicated and difficult to attain on many properties. Although there are four National Forests, a number of state-owned forests, parks and game-management areas, only 6% of the forest is in public ownership. Except for some large areas controlled by paper companies in northern Maine, the wood-using industries are not important owners of forest land. Nearly 70% of the forest land is owned by nonindustrial private owners. Because these owners have an overwhelming influence on the management of forests, they have been the subject of numerous surveys and questionnaires designed to probe their past use of their land and future intentions for using it. Three recently published studies on New Jersey, Delaware and southern New England (Kingsley, 1975; Kingsley and Finley, 1975; and Kingsley, 1976) have shown the same general trends in ownership changes and reasons for ownership.

Much forest land formerly associated with farms and other rural owners has moved into the control of urban and suburban people, mostly professional, managerial and skilled people. These new owners, unlike their former farm owners, do not look upon their holdings as a source of fuelwood and building material, or for commercial sale of timber to produce income. Although many say that they would not be averse to selling timber—provided such sales would not harm the recreation, wildlife, amenity or speculative values that induced them to purchase the land—they have no pressing need to obtain cash income from the land.

New Jersey owners are an exception. A recent tax change gives a very large tax reduction to those owners who obtain an annual income from their land. Because land taxes are increasing so rapidly, many owners have suddenly turned to foresters to guide them into commercial timber production.

Complicating the problem of encouraging multiple-use management is the short period of ownership. Nonindustrial forest properties change hands about every 15 years. Most owners are reluctant to invest money and effort in their forest when the benefits may accrue to the next landowner. Even those who take a long-term view of management of their forests are haunted by the thought that subsequent owners may destroy the economic and social values that they have created during their ownership. The average owner is about 50 years old, so he cannot expect to benefit personally from investments in forestry practices that will return income in the distant future.

To further expand the background in which the private forest exists, national and world-wide predictions of use and supply of forest products highlight growing relative scarcity as a result of increasing population, higher standards of living, substitution of wood-derived chemicals for petrochemicals, greater use of wood for fuel, and world-wide transfer of forestland to nontimber uses.

Foresters, wildlife biologists and other land-management specialists have the knowledge and techniques to increase the contributions that our forests can make to our regional welfare, but have the formidable task of transmitting this knowledge to two million private landowners and motivating them to act upon it. This is the problem that is being attacked through federal and state cooperative forestry programs.

ORGANIZATION OF FEDERAL PROGRAMS

The Forest Service, largest agency in the U.S. Department of Agriculture, has the primary responsibility for reaching the private forestland owner, although the Soil Conservation Service and the Federal Extension Service also are active in this work.

The Forest Service has three branches. **The Research Branch** develops better methods of growing, protecting and managing all the resources of the forests and associated range lands plus promoting the manufacture and use of forest products.

The National Forest System manages 80 million ha of national forests in 42 states for timber production, recreation hunting and fishing, grazing, wilderness recreation and watersheds. (These are often confused with national parks, such as Yellowstone and Glacier, which are under the jurisdiction of the Department of Interior. Logging is not permitted in the national parks).

The State and Private Forestry Branch administers the federal programs directed toward the private landowner as well as nonfederal public ownership. Federal funds and technical assistance are provided to the state foresters for fire control, suppression of disease and insect outbreaks, production of tree seedlings for reforestation and on-the-ground professional forestry advice to landowners.

This professional advice to the landowner reaches to the heart of our forestry problems in the Northeast. Unlike many countries that have strict controls over what an owner may do with this forest, we have no such public control. An owner may neglect or abuse his property, may completely remove the forest and convert it to a pasture, a housing development, or an industrial site. The United States has no mechanism for forcing the owner to manage his forest as a valuable long-term national resource.

Gentle persuasion and education in the long-term value of land stewardship are the principal tools used to move the private landowner toward good forestland management. The owner must be convinced that land management, which often results in cutting of some trees, will be beneficial to the

future value of the resource, if not immediately to him. Despite these serious obstacles to good multiple-use management of private forestland, the federal-state cooperative approach has had some success.

Early in the history of forestry in this country, it was recognized that one of the high priority forestry problems was to reduce damage by forest fires. In 1926, the Clark-McNary Act was passed, which provided matching federal funds to the states for prevention and control of forest fires. Through public education, plus enforcement of laws against setting fires, the number of man-caused fires has been reduced drastically. Those fires that start are now controlled by the efficient state fire-control organizations that have been stimulated by federal matching funds. These funds will exceed $3 million this fiscal year. The public is now firmly convinced that forest fires are harmful, and people cooperate in preventing fires and reporting those that do start.

Another very effective program was initiated in 1950 with the passage by Congress of the Cooperative Forest Management Act. It supplies $900,000 of matching federal money to the 12 Northeastern states to hire foresters to give on-the-ground assistance to private landowners and primary forest-products industries, such as logging and sawmilling. With the help of this seed money, the states have expanded their services to the landowner, so that state expenditures greatly exceed the mandatory matching of the federal contribution. Several hundred foresters are now employed in the land-management activities provided in this program. Planned activities in the coming year for the 12 states include the preparation of management plans for more than 5,000 owners with 108 000 ha of forest land, wildlife assistance to 838 owners with 5 000 ha, and forest recreation assistance to 500 owners with another 5 000 ha.

The service forester, at the request of the landowner, will walk through the forest with the owner, determine his goals in land management, and advise him how such goals may be reached. Frequently, the landowner does not realize the multiple values of the forest, knows little of the management options open to him and the methods to be used to achieve these options. The minimum result of such a visit is a better understanding of the methods and results of forest management applied to his property. If the property and plans of the owner as developed in this discussion warrant it, the service forester will inventory the forest resource and provide a written management plan for the owner to follow.

When this cooperative forest-management program was started in 1950, most requests came from farmers who wished to cut timber for sale or use on the farm. Frequently, the farmer looked to the service forester for help in marketing timber. Although he might also look upon his forest for wildlife and recreational values, his primary interest was often a cash sale or production of wood products for farm use.

But, as mentioned above, the trend in forest ownership has been away from the farmer and into the hands of professional, managerial and skilled workers. These owners seldom have purchased their land for the production of commercial wood products, but many know in a vague sort of way that land-management techniques may enhance nontimber values. The service forester, formerly oriented strongly toward timber values, is now changing his thinking and advice to meet these newly emerging needs. The State and Private Forestry Branch is helping to train the service foresters so that they will be competent to supply help on management of the nontimber resource.

The 1950 Cooperative Forest Management Act also stipulated that the Forest Service was to supply technical assistance to the various state foresters, as needed to help the service foresters keep abreast of the latest techniques in forest management as they are developed by the federal forest and range experiment stations, state agricultural experiment stations and schools of forestry. This training is important because the service forester is often working in remote locations without access to forestry libraries, and he may have little contact with the profession other than through his neighboring service foresters. He also has a large backlog of unfulfilled requests for assistance, which puts a premium on production.

Many in the State and Private Forestry Branch are former researchers; all work closely with research to transmit applied research results to the service forester as soon as they are developed. This is usually accomplished through training sessions in the field, where service foresters can be shown how to apply the results in their particular conditions.

Because wildlife management is often associated with forestry schools and with departments of natural resources at the state level and because many foresters have a personal interest in hunting, most service foresters have knowledge of habitat manipulation to favor game species. But many landowners are asking for information about improving habitat for nongame species, particularly songbirds, as well as techniques to enhance recreational and esthetic qualities.

In response to these new needs, the State and Private Branch in the Northeast is enlarging its expertise and training activities. The Branch now has a wildlife biologist devoting full time to nongame and rare and endangered species problems. Workshops have been held for loggers, landowners and service foresters on landscape-management techniques that will lessen the visual impact of timber harvesting.

Each national forest has landscape architects who

review planned timber sales, road construction, and recreational developments to ensure that the forest disturbance will not destroy the natural beauty of the forest landscape. These experienced landscape architects help in training the service forester, who then uses this knowledge in his consultations with the landowner and logger.

This fiscal year, Congress has appropriated half a million dollars for expansion of multiple-use assistance. This is a small sum; but if it produces significant results, it will be increased in the future. It can be used by the states for cost-sharing employment of wildlife biologists, landscape architects, recreation specialists, and range scientists to provide wider technical assistance to the service forester. The states have submitted proposals, and those that are most likely to meet pressing needs will be funded.

Through the years, a number of federal programs administered in conjunction with the state-employed service forester have provided direct financial payments to private landowners undertaking forestry practices that require immediate investment but have deferred returns. The largest current one is the Forestry Incentives Program, which reimburses the owner up to 75% of the cost of approved activities.

Most common in the Northeast is timber-improvement work, which includes noncommercial thinning of young stands, killing of cull trees that will never provide merchantable wood and crop-tree release. These operations not only allow the remaining high-quality trees to capture the growth potential of the site, but also open up the stand to stimulate growth of wildlife food plants on the forest floor.

Other practices for which incentive payments are provided are planting of trees, pruning to increase the production of clear wood, fencing harmful domestic livestock out of young stands, and construction of roads for access and fire control. In recent years, 14 000 ha have been treated annually with the assistance of the Forestry Incentive Program.

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DISCUSSION

Unidentified. What is the situation with respect to holdings of land between the federal government, state and private ownership? Is there any transition being made these days or is that fixed?

Watt. It's pretty well fixed. There's really not any great expansion in federal ownership. There's some money available in the water and land conservation fund to buy specific and rather small recreational areas but otherwise ownership is fairly well fixed.

G. Zinn (West Virginia, USA). You mentioned at one point the fact that in the United States we have very little in the way of land use and land management control that affects the small private landowner. Have you any thoughts that you'd care to share with us regarding the prospects for such control or the rationale for such control in the long-term future?

Watt. This has often been a hot subject in forestry and feelings have fluctuated. There has been a tremendous amount of discussion down through the years. I think the feeling of the forestry profession in general is to shy away from advocating extreme controls on what an owner can do with his land. I think we all appreciate that it's an important natural resource and that long-term management, long-term consideration of the benefits is essential but we also have a very strong tradition in this country of letting the landowner do what he wants. Now this is changing; I think in the last ten years it's probably changed more rapidly than in the preceding 100. We've become more interested in the ecological relationships of landscape, but we're still dealing with particular people who own this land who are very firmly opposed to anybody telling them what to do. I think there's going to be a continuing trend towards some sort of control. For example, Vermont has a rather strict law, Law 250, which puts very strong controls on some aspects of land management use and these controls are mainly there for the preservation of the landscape the way it was when the law was passed. It's designed to prevent rapid development in the land; it's designed to prevent winter sports developments at high elevations which in the past have ruined some very pretty areas in the state; it's designed to prevent rapid expansion of what could be rural slums ten years from now. So here's a situation with the New Englander who traditionally is supposed to have a pretty stiff backbone, but he's agreeing to some controls on his land. I think that we are going to see changes.

127.
Multiple Use Management of West Virginia Hill Land

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This is a discussion of recreational use of hill lands in West Virginia. Some background must be established before dealing with the more specifically recreational issues. West Virginia publicly identifies itself as "The Mountain State," but the designation "Hill and Mountain State" might be more apt. Geographers divide the state into three regions: the western, Ohio Valley area, which is a relative flatland; the Allegheny Highlands, containing the central mountain ridges of the state; and the eastern, ridge and valley province, with its unusual trellis drainage system. Anyone who has travelled in West Virginia knows there is much steep hill land in each of the three geographic areas. *The West Virginia Soil and Water Conservation Needs Inventory* (1970) places 61% of all West Virginia land in Category VII, defined as having soils with "severe limitations, making them unsuited for cultivation and restricting their usage largely to grazing, woodland, or wildlife." The same survey places only .5% of West Virginia's land in Category VIII, limiting usage to recreation, wildlife, water supply, or aesthetic purposes.

West Virginia's land lends itself to many uses. West Virginia resembles hill land anywhere, while having a number of features guaranteeing its uniqueness. The McGraw-Hill *World Atlas* indicates that West Virginia lies in the center of the world's largest hardwood forest. Between 1870 and 1920 some 30 billion boardfeet (23.2 million m^3) of lumber were removed from West Virginia. West Virginia also is in the center of the eastern coal mining industry, producing about 10% of the nation's coal annually. Some 80% of the state is forested with less than 20% being suitable for agricultural purposes. This Hill and Mountain State has been relatively slow to develop, having transportation and economic difficulties common to mountainous geographic areas.

In recent years, West Virginia has sustained considerable economic growth. Timber prices have increased, the value and importance of coal has increased greatly, wages for coal miners have improved considerably, there has been considerable development in the chemical industries centered in Charleston and Huntington, new highways and superhighways have been built, residential development has expanded, and a great number of recreational enterprises have begun competing for the recreational monies of the inhabitants of the eastern seaboard and other more central population centers such as Cleveland, Detroit and Cincinnati.

In 1973, 85% of the people visiting West Virginia came from either the North Central or the Middle Atlantic States, according to the Bureau of Business Research of West Virginia University. Of those visiting West Virginia that year, 57% came to visit friends and relatives, while only 18% came for sightseeing and outdoor recreation. From additional research by the same bureau, it is expected that the tourist and recreational trade will increase sharply in the next decade.

The purpose of this paper is to make this point: with all the emphasis on the resources of hill land, one should not overlook the non-consumptive recreational values of hill land. Almost any land can be used for some recreational purposes. An area 30 cm square can support a bird bath; a little larger area can support a card or picnic table; at the other end of the spectrum, even huge strip mine areas in their unreclaimed state permit some hunting. But it may well be that only a limited number of recreation developments of certain kinds is possible or profitable in a given area, because recreation "for the masses" can be overdeveloped, and indeed, lose essential elements of its recreational character.

There is a tendency to assume that recreation means ski-lifts, hiking trails, camp grounds or amusement parks. But recreation means first of all the enlarging and ennobling and enriching of the human spirit. Aesthetic delight—the perception or awareness of beauty—is the soul of recreation. With respect to hill land, the aesthetic delight comes from the sight, the smell, the feel of the hills. Land in its undeveloped state may offer the very highest of recreational experiences, non-monetary as these may be.

Having proposed the basic thesis, that hill land offers a wide variety of recreation usages, and having suggested the presenter's prejudice, that the non-consumptive forms of recreation deserve attention, respect, and encouragement, let us look at some of the recreational uses of hill land in West Virginia. The Core Arboretum on the Evansdale Campus of West Virginia University in Morgantown is an excellent example of an educational and relaxational use of land that would otherwise be difficult to develop. The pleasant walkways and comfortable resting areas

invite people to sit in the shade of the trees, or observe the many birds that visit this forest. The Arboretum is used as a teaching facility by several departments in the University, the Division of Forestry finding it an especially convenient teaching laboratory.

One of the world famous locations of West Virginia is Harper's Ferry. Robert Harper began running a ferry in 1747 at the juncture of the Potomac and Shenandoah rivers and not much later Thomas Jefferson called the view "worth a voyage across the Atlantic." This was said, one must remember, in the era of wooden sailing vessels long before the era of travel agency superlatives. In 1796, George Washington determined that the site should become the National Armory, and muskets and rifles were built there until the factories were destroyed in the Civil War. Raging rivers have inundated the town several times, and now the town would be desolate, if it had not been made a major tourist attraction. In spite of the view of Maryland and Virginia hills, the location is actually the lowest point in West Virginia, a mere 76 m above sea level.

Harper's Ferry is the only national historical park in West Virginia, but the state boasts of three national forests, small sections of the Jefferson and Washington National Forests, and almost 360,000 ha in the Monongahela National Forest.

The Monongahela National Forest lies in the Allegheny Highlands region and is composed of sparsely settled counties. Tucker and Pendleton, for example, each have a population of little more than 7,000, Pocahontas County has 9,000, while Randolph County, at 25,000, has more citizens than the other three counties combined. Logging is the major industry in these counties, while tourism constitutes an important secondary source of revenue. In this national forest are three areas of considerable popularity: Seneca Rocks, where technical climbing can be practiced; Dolly Sods, a relatively barren area where the problems of forest succession are most easily evident; and Otter Creek, a wilderness area of delicate and fragile beauty.

West Virginia has established 35 state parks as well as 9 state forests. These parks and forests are, with only a few exceptions, exemplars of the use of hill land for recreational purposes. Hawk's Nest and Coopers Rock have scenic overlooks over vast gorges, but it would be difficult to walk a level kilometer in any of the state parks or forests. The parks are recreation areas of differing calibre, being day-use parks, historical or scenic areas, or family vacation resort parks. Canaan Valley is a large state-run ski resort, while Tomlinson Run caters principally to day-use summer swimmers. The state operates the last of the logging railroads using Shay engines on one of the longest and narrowest state parks anywhere: 20 km long and 15 m wide. The "Cass Scenic Railway" offers spectacular views of the area and is especially popular in the fall, when the autumn leaves are superabounding in color and the weather is comfortable to slightly chilly. The 20-km ride offers a change in elevation of 800 m.

Commercial recreation developments in West Virginia have not met with outstanding success. The most notorious problem area is Snowshoe, an ambitious attempt at developing a large ski resort in the southern Monongahela National Forest. But even small enterprises, such as amusement parks, have not fared very well. West Virginia has been overwhelmingly rural, and, until recently, its inhabitants have been relatively poor. In America, wealth has always gone together with big cities, and it would take the total population of the six largest cities in the state to add up to half a million people. In fact, the population of the entire state does not add up to the number of citizens of the city of Los Angeles!

The financial conditions of West Virginians are improving considerably, and while urbanization is proceeding rapidly, the population is still predominantly rural, and the recreation needs of rural people are much different from the recreational needs of urban inhabitants. Rural West Virginians do not need hill land areas especially set aside for their recreation, because they live on hill land, enjoy the scenic vistas, the relative solitude, the awareness of the change of seasons, and the propinquity of outdoor exercise. Depending on the location, the clientele of West Virginia hill land recreational developments may be as much as 80% out-of-state people. Part of the justification of the state parks system lies in the fact that they bring in people from other states who then spend some money in West Virginia. Over 50% of what travelers spend is spent on transportation and meals. Pipestem, for example, called "the crown jewel of the state park system," is a virtual paradise of recreational facilities, with an outdoor pool, an indoor pool and sauna bath, a pavilion, stables, bicycles, tennis courts, golf courses, and indoor game room. The Park is but a few km from the Virginia border, bringing in almost half a million out-of-state visitors a year.

The West Virginia University Bureau of Business Research affirms that recreation has great growth potential, especially in the central regions of the state. The conjecture is that the usage of established recreation areas will increase at a 10% annual rate for several years. Although the federal government has shown interest in building some "scenic highways," West Virginians of the Izaac Walton League and the Highlands Conservancy would prefer that more be done to preserve the beautiful areas of the state, rather than encourage and facilitate greater

tourist use. The picture is one of slow and deliberate growth, rather than any form of Orlando-like, Disney-world explosion.

West Virginia offers great opportunities for recreational and aesthetic activities. As the resources of West Virginia are surveyed, the mountains must themselves be accounted as a primary resource. As Hillary climbed Everest "because it was there," so too tourists and recreators will continue to come to West Virginia's hill lands just because and as long as they are there. The recreational resources of West Virginia need to be planned for and managed, but their appeal and intrinsic value are immense and awesome. There is a middle eastern proverb that says that a woman of great beauty need never fear for her upkeep. In the same way, the beauty of the state of West Virginia should be enough to keep its inhabitants well cared for. The prostitution of her natural resources is a clear and persisting danger. No doubt some hills will be denuded of their forest cover, and some will give way to strip mines. But hopefully a majority of the hills of this state will remain for the relatively nonconsumptive uses of recreation and aesthetic enjoyment. Such use may not always offer the greatest financial return, but, once the basic necessities of life have been taken care of, what else is the making of money for, if not for recreational and aesthetic concerns? For West Virginia's hills, we could do no better than wish for such higher usages.

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129.
Dairy Beef Production in the Guatemalan Highlands

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Guatemala is located between 14° and 18° latitude and 88° and 92° longitude and has an area of 108 900 km^2. About 30% of this area is more than 1 000 m above sea level with slopes of from 5 to 75%. These highlands run from west to east through the middle part of the country and are inhabited by 65% of the total population. Close to 96% of the farms located in this area have less than 22 ha each, but they occupy only 40% of the land. Their main crop is corn (about 65% of the cultivated area) which is produced for human consumption. Coffee, food legumes, wheat, fruits and vegetables are also grown. Cattle and sheep grow on natural pasture supplemented with corn stover and other low quality forages during the dry season. Forage supplementation with other feeds or nutrients is not a common practice. In general, these farms are exploited using traditional technology, that is, without modern cultural practices, a minimum of physical inputs and low labor requirements. It is not surprising, therefore, that under the prevailing conditions, crop and livestock productivities are very low; furthermore, this low productivity is highly correlated with other signs of underdevelopment and poverty such as poor education, bad health and undernutrition.

Clearly, the situation in the Guatemalan highlands basically constitutes a social and economic problem that requires political solutions, but the implementation of these policies will need new technology that can be applied under the ecological and socioeconomic conditions of the area.

This technology has to be characterized by relatively modern cultural practices, moderate use of capital and physical inputs and high labor requirements. It has to be integrated also into production systems that yield foods of vegetable and animal origin. The development of a system with these characteristics has been one of the objectives of the Division of Agricultural and Food Sciences of the Institute of Nutrition of Central America and Panama (INCAP). The results obtained to date on the production of beef from dairy calves applying this system are presented in this paper.

LOCATION OF FIELD TRIALS

The studies were carried out at INCAP's Experimental Farm, located 40 km northeast of Guatemala City, at an altitude of 1 500 m above sea level; its soil is classified as heavy loam. The annual rainfall and temperature of this region range from 940 to 1 500 mm, and from 10 to 20 C, respectively. These

characteristics are typical of the Guatemalan highlands, where corn is the main crop. The farm has a total area of 45 ha distributed as follows: 12 ha dedicated to the production of corn grain and stover, 4 ha to the production of corn plant silage, 4 ha to that of black beans, and 4 ha for fruits and vegetables; 19 ha are covered by forest, and animal facilities and headquarters occupy the remaining 2 ha. The slope varies from 5 to 15% in the area cultivated with crops and from 15 to 60% in the remaining area.

In addition to corrals and pens for dairy beef production, there are also facilities for dairy cows, sheep, pigs and chickens. Animal production is integrated with crop production, thus making maximum utilization of available resources.

FORAGE PRODUCTION

Corn grain and black beans are harvested once a year, with average yields of 3 330 and 1 400 kg/ha/year, respectively. In addition, the first crop produces 9 100 kg of air-dried corn stover/ha/year, a forage that comprises all the stalks, leaves, flowers, and husks that remain in the field after harvesting the grain. Yields of corn grain and black beans are 6 to 8 times greater than in surrounding farms. The corn plant grown for silage is harvested twice a year before the grain is in the milky stage, producing 65 000 kg of silage/ha/year. Trench silos are used for this purpose, and to improve silage quality, 5% of sugarcane molasses is added at the time of ensiling.

Coffee pulp, a by-product of the coffee-processing industry, is abundant in the area. This material is used when needed, either as silage or dry, as a substitute for corn stover and corn silage.

GENERAL CHARACTERISTICS OF THE DAIRY BEEF PRODUCTION SYSTEM

Male Holstein calves are available from dairy farms located in the same region. These calves have a higher genetic potential for beef production than native animals, but they are sacrificed at birth because dairy beef production is uneconomical when traditional feeding systems are employed. Therefore, our studies were conducted to develop an economic dairy beef production system that could be applied on small farms of the Guatemalan highlands.

The calves went through the following growing and finishing stages: Artificial rearing of calves, from one week to four months of age; development of calves, from four to twelve months of age; and finishing of steers, from twelve to eighteen months, at which age they were sold for slaughter, weighing 400 to 440 kg.

During these three stages, the animals were kept in corrals or pens of very simple design, and fed the minimum possible amounts of milk and concentrates and a maximum of forages.

Artificial Rearing

After receiving enough colostrum during their first week of life, calves were housed in stables and kept in small individual corrals maintained under strict hygienic conditions. As a result, mortality rate during this stage has been less than 10%.

The feeding plan used at this stage is presented in Table 1. Calves were fed a total of 168 l of milk

TABLE 1. Feeding plan for artificial rearing of dairy calves

		Daily Feeding		
	Weeks*	Whole Milk l**	Starter	80% Ground Corn Stover + 20% Molasses
	1	2	*Ad libitum*	
	2	3	↓	
	3	4	↓	
	4	4	↓	
	5	3	↓	
	6	3	↓	
	7	3	↓	
	8	2	↓	
Weaning	↓		↓	*Ad libitum* ↓
			Up to a maximum of 3 kg/day ↓	
	17		↓	↓

*After one week of age.
**Offered twice a day.

during the first eight weeks. Beginning the first week they received a ground starter concentrate that contained 16% crude protein and 2.7 Mcal/kg digestible energy (Table 2). The main ingredients of this concentrate are produced locally and consequently the cost of the concentrate is about half as much as that of the commercial starters available in the market. The starter was fed *ad libitum* up to three months of age and then limited to 3 kg/head/day. An average of 232 kg of concentrate was consumed by the animals during this stage. After weaning, calves were transferred to open corrals with a shaded area, concrete-slatted floors and common feed bunks, and fed *ad libitum* a mixture of 80% ground corn stover and 20% sugarcane molasses. The average total consumption of this forage was 70 kg.

The results obtained with the feeding system detailed above are presented in Table 3. Animals gained from 0.45 to 0.55 kg/day before weaning,

TABLE 2. Composition and nutrient content of calf starter

Ingredients	%
Cottonseed meal	26.0
Wheat bran	25.2
Sugarcane molasses	16.0
Ground corn stover	28.0
Bone meal	2.1
Calcium carbonate	1.5
Salt	0.5
Trace minerals + vitamins*	0.2
Aurofac-10**	0.5
Total	100.0
Nutrient content	
Crude protein, %	16.4
Crude fiber, %	12.5
Digestible energy, Mcal/kg	2.7

*Premix containing the following vitamins per pound: A, 1,200,000 IU; D_3, 200,000 IU; E, 1,000 IU; thiamine, 100 mg; B_6, 40 mg; riboflavin, 150 mg; nicotinamide, 400 mg; pantothenic acid, 200 mg; choline chloride, 10,000 mg; B_{12} mg, 1.0. The premix also contained the following minerals: Ca, 2.2%; P, 1.8%; Mn, 1.1%; Mg, 2.0%; Zn, 2.2%; Fe, 1.3%; Co, .176%; I, 066%, Cu, .015%.

**An antibiotic supplement source purchased from American Cyanamid and supplying 10 g chlortetracycline.

TABLE 3. Average calf performance during artificial rearing

	Weeks of Age	
	2–9	2–17
Initial weight, kg	35.0	35.0
Final weight, kg	63.0	105.0
Daily weight gain, kg	0.5	0.6
Daily dry matter intake, kg	1.4	2.6
Kg dry matter/kg weight gain	2.8	4.3

and from 0.7 to 0.8 kg/day after weaning. Average daily gain for the whole artificial rearing period ranged from 0.60 to 0.68 kg. Dry matter intake increased very rapidly after weaning, reaching up to 4.5% body weight when calves were four months of age. This level of intake is higher than that observed with low-fiber, high-grain concentrates in studies reported by other workers (Roy, 1970).

Development and Finishing

During the developing and finishing stages the animals were fed forage *ad libitum* and supplemented with small quantities of concentrates. When calves were four to twelve months of age they received a mixture of 80% chopped corn stover and 20% sugarcane molasses, and from the age of twelve to eighteen months, they were fed corn silage. The forages used had a low crude protein content (Table 4), therefore, they were supplemented with high protein concentrates (Table 5). These concentrates were prepared with the same ingredients used for the calf starter. The corn stover-molasses mixture was supplemented with 2 to 3 kg of supplement A/head/day during the development stage, while corn silage was supplemented with 3 to 4 kg/of supplement B/head/day during the finishing stage.

TABLE 4. Chemical composition of forages for developing and finishing of steers

Components	Corn Stover	Corn Silage	
	As Fed	As Fed	Air-dry
	%	%	%
Dry matter	90.0	25.0	90.0
Ether extract	1.6	0.7	2.5
Crude protein	4.5	1.5	5.4
Ash	5.4	2.4	8.6
Crude fiber	37.0	7.1	25.7
Nitrogen-free extract	41.5	13.3	47.8

TABLE 5. Composition and nutrient content of concentrates used as forage supplements

Ingredients (%)	Supplement A	Supplement B
Cottonseed meal	56.0	40.0
Wheat bran	—	16.0
Sugarcane molasses	21.0	21.0
Ground corn stover	19.0	19.0
Mineral mix*	4.0	4.0
Total	100.0	100.0
Nutrient content		
Crude protein, %	5.0	20.0
Digestible energy, Mcal/kg	2.8	2.8

*Contained: Ca, 23%; P, 12%; NaCl, 18%; I, 0.009%; Fe, 0.2%; Cu, 0.01%; Co, 0.01%; Mn, 0.006%; Zn, 0.01%.

Animals had free access to mineralized salt and water all the time. They were dewormed periodically and received intramuscular doses of 1 000 000, 150 000 and 100 IU per month of vitamins A, D and E, respectively. Under these conditions, mortality rate is less then 3% during the development and finishing stages.

As the data in Table 6 indicate, animal performance with the feeding system outlined has been satisfac-

TABLE 6. Average performance of calves and steers during the developing and finishing stages

	Development (8 mo.) Corn Stover + Molasses + 2 – 3 kg/day of Supplement A	Finishing (6 mo.) Corn Silage + 3 – 4 kg/day of Supplement B
Body weight, kg		
Initial	100-110	260-280
Final	260-280	400-440
Daily gain	0.6-0.8	0.8-1.0
Forage intake, as fed		
kg/day	4.0-5.0	32.0-38.0
% body weight	2.1-2.5	9.0-11.0
Forage dry matter intake		
kg/day	3.4-4.3	8.0-9.5
% body weight	1.8-2.3	2.3-2.7
Total dry matter intake		
kg/day	5.1-6.9	10.6-13.0
% body weight	2.6-3.5	3.0-3.7
Kg dry matter/kg weight gain	8.5-10.0	12.5-14.0

tory. Average daily gains ranged from 0.6 to 0.8 kg in the development stage, and from 0.8 to 1.0 kg in the finishing stage. At this rate of gain the steers reach the required final weight at 18 months of age. Average dry matter intake, as percent of body weight, was 2.2 for the corn stover-molasses mixture and 2.5 for the corn silage. Digestibility trials conducted with steers have shown that dry matter and protein digestibilities of the corn stover and corn silage rations are 58, 60, 56 and 60%, respectively.

The data reveal that supplemented corn stover and corn silage can produce adequate animal performance in a semi-intensive system for dairy beef production. Table 7 shows the animal production per ha that can be obtained with this system. As observed, the number of animals that can be fed with the forage produced in one ha, and the live weight gains that they can reach with this forage when supplemented with small amounts of concentrates, are considerably higher than in most cattle production systems used in Latin America (Caballero, 1971; De Alba, 1971).

ECONOMIC STUDIES

The feeding trials conducted at INCAP's Experimental Farm have shown that with adequate management and feeding techniques, the biological efficiency of livestock production in the Guatemalan highlands can be improved considerably. Application of this technology by the farmers will require not only biological but also economic efficiency. Therefore, a study was conducted to determine the economic feasibility of the dairy beef production system described above when applied on a farm with an area of 20 ha. This is considered the minimum farming area for productive agriculture in that particular region of Guatemala.

TABLE 7. Annual production of forage and animals

	Stages: Development, Corn Stover + Supplement	Finishing, Corn Silage + Supplement
Forage production/kg/ha/year	9 100	65 000
Animal units fed/ha/year (carrying capacity)	6	5
Number of animals produced/ha/year*	9	10
Live weight gains/kg/ha/year	1 550	1 650

*Eight months for development and six months for finishing.

It was assumed that the ecological conditions and the production level of corn grain and forage were the same as those prevailing at INCAP's Experimental Farm, that the farmer owned the land, and that this was his only source of income. It also was assumed that the farmer had access to credit and technical assistance so that he could apply the needed technology without restrictions. The study was designed for a nine-year period. Out of the 20 ha, 9 were assigned to corn grain and stover production, 9 to corn silage production, and 2 to animal housing facilities and the family's living quarters. Table 8 presents a summary of the economics of the project and reveals a 10% capital return over investment. This is good enough to encourage a more efficient livestock production in the Guatemalan highlands. Field trials are now being planned to determine the biological and economic efficiency of the system described in this paper when applied in several parts of the country.

TABLE 8. Summary of the economic analysis of the model 20-hectare farm for a nine-year period

Average annual sales (cattle and corn grain)	$15,628.00
Average annual costs	11,808.00
Average annual profits	2,487.00
Profits over sales	16.0%
Profits over investment	10.0%

Logically, results will vary according to the conditions and resources available in those particular areas, and the technical capacity of the people in charge. In any case, partial or total application of a system such as the one described herein would certainly contribute to increased land productivity and human well-being in the Guatemalan highlands.

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DISCUSSION

K. O'Connor (New Zealand). In illustrating your neighborhood farm where the crop was very poor, you said that it was difficult to have this farmer improve his methods. From reading the approach that you took of identifying first the social and political problems and so on down to establishing the need for technical development appropriate to this situation, I found no disagreement with that approach and the principles. But I wonder if you could tell us what the farmer across the way saw about the system that he did not want to adopt?

Cabezas. I think that it is not that they don't want to adopt it. It's that they cannot adopt it because they don't have access to economic and technical assistance. We, as an institution, cannot give that assistance and these people live in that area just for part of the year and they migrate toward the lowlands for work during the rainy season and the crop season. So I believe that it is not that they don't want to adopt it, it's just that they can't. Their condition doesn't allow them to do that. They don't have the facilities, they don't have the economic assistance, especially. Even if they work in our farms, because some of them work our farms and they know these things work, but when they come back to their farms they do not try it. I believe that has to do with, not only education, but with the whole social and economic problem.

O'Connor. Therefore, I find it difficult to understand why you want to do the field evaluation of this system.

Cabezas. We are doing the field evaluations together with a program of the government since they already made a political decision to distribute some land. We are not doing it with the regular farmer that has one or two ha but there is a program, agrarian reform is going on, in sections of Guatemala and San Salvador and there we are working with them. But under those conditions I feel that we have a chance to succeed. But if the government doesn't accept the political decision, I think that all we can do is wait and develop more knowledge so that when those conditions come, we can apply that knowledge.

130.
Beef Production on Sloping Land in Southwestern Wisconsin

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Early work concerned with the improvement of permanent pastures in Wisconsin led to the pasture renovation concept and the development of a practice which has been recommended, with certain modifications, to the present time. Production from unimproved permanent pastures on sloping land was found to be very low and extremely variable, ranging from almost zero in woodland pastures to about 2.25 MT/ha of dry matter on the better sites without trees and brush. On these better sites about 112 kg of beef per ha per year have been produced.

PASTURE RESEARCH ON SLOPING LAND IN SOUTHWESTERN WISCONSIN

The Lancaster Experimental Farm was established in southwestern Wisconsin in 1962 to evaluate farming practices for promoting a productive agriculture embodying soil and water conservation on sloping land on the Upper Mississippi Valley unglaciated soils. The Fayette-Dubuque and associated soil types comprise an area of about 5 million ha, distributed across southwestern Wisconsin, southeastern Minnesota, northeastern Iowa and northwestern Illinois. Much of this land should remain in permanent vegetative cover. There are approximately 770 000 ha of unproductive permanent pasture on this steep land in Wisconsin alone, and more than 400 000 ha, or 52% of this area, have slopes of 6–30%. Much of the research and demonstrational work at this farm is planned and conducted by a committee composed of research personnel from the four states in the region.

The Lancaster farm receives an average of 860 mm of precipitation per year, two-thirds of it during the growing season. The average annual temperature is about 9.5 C, with May 12 the last day in spring with minimum temperature of 0 C and October 14 the first day in fall with minimum temperature of 0 C.

OBJECTIVES

General: (1) To develop systems of forage production and utilization with beef cattle in the sloping unglaciated Upper Mississippi Valley region with cooperation from the four-state committee.

Specific: (1) To evaluate species and mixtures of perennial forage crops for grazing beef cattle. (Some grasses with nitrogen fertilizer were compared to the same grasses grown in association with alfalfa or birdsfoot trefoil.) (2) To determine the feasibility of deferring the grazing in summer, followed by utilization of this accumulated growth in late autumn. (3) To evaluate the feeding of limited supplemental energy from corn grain to increase rate of gain for cattle finished to a satisfactory slaughter grade at the end of the pasture season.

METHODS AND MATERIALS

The production of forage and beef from renovated permanent pastures on south-facing, 10 to 12% sloping unglaciated Dubuque silt loam soil is being studied in southwestern Wisconsin. The Fayette, Dubuque and other closely related soil series developed under a deciduous hardwood type vegetation and are predominantly found on rough, broken land. Pasture production and utilization are being evaluated with yearling beef cattle, using a put-and-take system of stocking. With this system, certain uniform animals that remain on the experimental pastures all season are classified as "testers." Others that are added or removed to utilize the pasture growth are "grazers" which graze reserve pastures when not needed on the experimental pastures. The total gains per pasture and per ha are calculated from daily gains of testers corrected for the number of steer days for any period. Steers are weighed every 28 days, with a 14–16-hour fast from feed and water only at the beginning and end of the pasture season. Experimental 1.21-ha pastures, divided into three subpastures for rotational grazing management, have been utilized. The soil has been limed to pH 6.5–6.8 and P and K maintained at recommended levels. Pasture treatments have been duplicated each year and each experiment has been repeated from 3 to 5 years. During the critical fall period, from about September 1 to October 15, experimental pastures have been allowed to make uninterrupted growth in preparation for winter.

RESULTS

1967–1970

Five pasture treatments were compared (Table 1). The production from mixtures of selected grasses

TABLE 1. Performance of yearling steers grazing renovated pastures with nitrogen supplied by either N fertilizer or legumes (1967–1970, incl.)

Pasture Treatments[a]	Average Gain[b] Per Tester (kg)	Steer Days[c] Per ha (days)	Daily Gain Per Tester (kg)	Total Gain[d] Per ha (kg)
Ky bluegrass-timothy-redtop				
N-0 Kg/ha	65.5	422	.56	236
N-134 Kg/ha	55.3	743	.47	349
Birdsfoot trefoil	62.0	644	.55	354
Bromegrass-orchardgrass				
N-134 Kg/ha	55.3	743	.47	354
Alfalfa	48.6	836	.42	351

[a]Two replicates, each 1.21-ha in size, divided into 3 subdivisions for rotational grazing.
[b]Average of 3 tester animals which remained on pasture all season.
[c]Calculated from total number of animals (testers plus grazers) for the season; 28-day weighing periods.
[d]Calculated from average daily gain of testers, multiplied by the number of steer days per ha.

with 134–168 kg N/ha was not different from these grasses in mixtures with alfalfa or birdsfoot trefoil. Live-weight gains during an average grazing period of 116 days were 352 kg per ha per year. A renovated pasture composed of the same grasses but without added N produced 230 kg of beef, which was less ($P < .05$) than those with N or legumes, but more ($P < .05$) than the typical 112 kg from unimproved pastures.

The cost of production was less in pastures where N was supplied by legumes. Rate of gain was less than .6 kg per head per day and steers were still classified as feeder cattle at the end of the pasture season. This indicated the need for subsequent work to lengthen the pasture season and to attempt to increase daily gains with limited supplemental energy from corn grain.

1971–1974

During this period, some new pastures were established, and the objective was to evaluate deferring late summer grazing as a means of saving pasturage for use in late autumn, thus lengthening the pasture season. Cattle grazed reserve pastures during August and September and returned to utilize accumulated summer growth. (On most farms there are haylands scheduled to be plowed in the rotation and third growth on these may be grazed during the fall when long-term pastures should be rested.) Birdsfoot trefoil replaced alfalfa in grass-legume seedings to be grazed subsequently.

Yields from small pilot plots within experimental pastures during the 1967–1970 period showed that these grasses gave a significant response to 224 kg per ha of N per acre and consequently the rate was increased to this amount in 1971.

Performance of steers during the 1972, 1973 and 1974 grazing seasons is shown in Table 2. The increase in yield over the previous years was probably due to the increase in N level in addition to the longer grazing season. Despite the longer grazing season under the conventional system, the number of steer days was similar and because the average daily gains were higher for the grass-legume pastures, the gains per ha were not different; the average was 517 kg per ha per year with a range of 496 to 556.

The oat companion crop used in the 1971 seedings was grazed; it provided 43 days of grazing, 105 steer days and 172 kg of beef per ha. (Farmers are sometimes reluctant to renovate because pastures are taken out of production during most of the renovation year; these data show higher production for the short grazing season with the oats; 172 kg per ha compared to the 112 kg from typical unimproved pastures.)

1975–1976

Results of the 1975 pasture season are shown in Table 3. The corn grain, fed at 1% of body weight after July 1, increased rate of gain and gain per ha. However, average daily gains, even for the grain-fed cattle, for the entire season were below 0.7 kg per head per day except for cattle grazing birdsfoot trefoil-grass pastures and only a few of the cattle had reached low-choice grade at the end of the pasture season. We have concluded that grain feeding should begin as soon as cattle go to pasture. May and June pastures are succulent, high in protein but low in dry matter and energy.

Performance of the steers receiving grain from the beginning of the pasture season until the end of July, 1976 is shown in Table 3. Results for the year are incomplete, but these data for three 28-day weigh periods are complete and show that we have been able to get gains of 1.0 kg or more with grain feeding during the first part of the grazing period. We expect

TABLE 2. Performance of yearling beef steers grazing renovated pastures under different summer and fall managements (1972–1974, incl.)

Pastures and Management	No. of Grazing Days	Steer Days Per ha	Average Daily Gains (kg)	Live Wt. Gains (kg/ha)
Trefoil-bluegrass, timothy, redtop				
Conventional				
Summer	123		.71	431
Fall	29	275	1.38	96
				527
Deferred				
Summer	84		.70	308
Fall	39	244	1.10	197
				505
Brome and orchardgrass, 224 kgN/ha				
Conventional				
Summer	123		.53	432
Fall	29	368	1.25	66
				498
Deferred				
Summer	84		.56	357
Fall	39	348	.71	179
				536
Bluegrass, timothy, redtop 224 kgN/ha				
Deferred				
Summer	84		.57	331
Fall	39	332	.98	224
				555

to be able to market choice grade cattle at the end of the extended pasture season in early November based on these early season results.

DISCUSSION

Permanent pastures on sloping land generally represent an undeveloped resource with a high potential for improvement. Pasture renovation involving liming, fertilizing, tillage, seeding and management is a practice that can accomplish this. Research is needed to refine the procedure under different field conditions (Scholl *et al.*, 1970).

The pasture research reported here has shown that mixtures of certain grasses and legumes were as productive as these same grasses fertilized with moderately high rates of commercial N. The cost of legume seed and sowing just once during the conduct of these trials was much less than the current cost of annual applications of N fertilizer (Scholl *et al.*, 1974).

The productive life of perennial legumes is enhanced by allowing them to make uninterrupted growth for a period of about six weeks prior to the end of the growing season; this management is probably beneficial to the grasses as well. However, the growth that accumulates during this 6-week period may be utilized in the fall without damage, provided a 4- to 6-inch stubble is left (Smith, 1975). Extending the pasture season by deferred grazing resulted in a substantial increase in beef production. Daily gains were higher during the cool weather of autumn when fly populations were lower than during the rest of the grazing season.

Interest in evaluating limited supplemental energy for finishing beef cattle on pasture has increased (Barrick *et al.*, 1973; Spooner and Ray, 1972). The feasibility of feeding corn grain to pastured yearling cattle, at 1% of their body weight, throughout the pasture season is being studied. Feeding at this rate after July during 1975 improved gains per ha but did not improve slaughter grade over cattle not receiving corn. Data from the 1976 season, not yet completed, indicate that the cattle fed corn throughout will grade "choice" at the end of the grazing season.

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TABLE 3. Performance of yearling steers grazing renovated pastures with or without corn grain fed at 1% of body weight, 1975–1976

Feeding Management	Performance of Yearling Steers[a]					
	Pasture Treatments					
	Bluegrass, Timothy and Redtop with: N-224 kg/ha		Birdsfoot Trefoil		Brome-orchardgrass with N-224 kg/ha	
	No Corn	Corn After 7/8	No Corn	Corn After 7/8	No Corn	Corn After 7/8
			1975			
Pasturage only						
May 13–July 8						
ADG (Kg)	.40	.26	.67	.64	.14	.29
Pasturage with or without corn[b]						
July 8–Sept. 9						
ADG (Kg)	.32	.73	.72	.84	.46	.69
Oct. 7–Nov. 3						
ADG (Kg)	.95	1.24	.60	1.17	.79	1.32
Total season (114 da)						
ADG	.56	.60	.68	.82	.55	.68
Kg/ha	351	547	422	581	291	571
			1976			
Pasturage with or without corn[b]						
May 6–July 28 (82 da)						
ADG	.75	1.15	.99	1.16	.76	.97

[a]Treatments with two replications except bluegrass mixture with N-fertilizer. Four tester animals in each pasture.
[b]Coarse-ground shelled corn hand-fed at 1% of body weight.

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DISCUSSION

R. Blaser (Virginia, USA). There is no doubt that there's an energy shortage. However, older data would show by supplementing grain at 1% bodyweight for the last 80 days, produced animals grading "good." Also, in Virginia work which I did not report—taking normal animals without grain feeding in the spring and then supplementing at 1% bodyweight, self-fed, by controlling intake with salt, done by my associates at VPI—that those animals for the season would gain two pounds. Of course we have longer grazing seasons than you do there, and again, many of those would be "high good" and "choice," ideal animals. So in our region it can be done with a minimum amount of grain feeding. I would like to ask a question, though. I did not mean to infer in my paper that the autumn growth was not good quality. We enforced better than 85% utilization by the cows. The calves gained nicely since they did not have this enforced utilization. We don't know what this growth is worth in terms of energy intake. To what do you attribute the higher intake and higher gain from autumn growth than from summer or spring growth?

Scholl. There are possibly three explanations—it's cooler, there is no fly problem and physiologically these animals may be stimulated to put on fat in the cooler seasons. Actually, with the put-and-take system that we use, we leave the cattle out there until that growth is all consumed and we don't waste feed. And so we're really converting all of this into beef. Those are the only things I can say about this. These cattle are a little larger then. I want you to understand that had we been using two-year-olds we might have obtained a different result. These people want to take those calves directly out of the wintering ration through a pasture season and put them on the market without going through the season.

131.
Pasture Management and Beef Production in the Southern Piedmont[1]

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The Piedmont region of southeastern United States comprises a rolling upland plateau lying between the Blue Ridge Mountains and the Coastal Plains. It covers about 152 810 km^2 with elevations of from 90 to 305 m above sea level. Normal precipitation ranges from 114 to 140 cm/yr. and the freeze-free period is 200 to 250 days. Soil textures tend to be heavier than those of the Coastal Plains region. Summer perennial grasses include bermuda (*Cynodon dactylon* [L.] Pers.), bahia (*Paspalum notatum* L.) and dallis (*Paspalum dilatatum* Poir.). Winter grasses include tall fescue (*Festuca arundinacea* Schreb.) and occasionally orchardgrass (*Dactylis glomerata* L.). Perennial legumes adapted to the region include white clover (*Trifolium repens* L.) and sericea lespedeza (*Lespedeza cuneata* [Dumont] G. Don.). Both cool- and warm-season grasses produce well at different seasons, and year-round forage production is possible in some years. Annual cereal grasses such as rye (*Secale cereale* L.) and annual legumes, crimson clover (*Trifolium incarnatum* L.), arrowleaf clover (*T. vesiculosum* Savi) are used. From early December to mid-March, low temperatures severely restrict growth of grasses and legumes. Additionally, soil water stress is often a limiting climatic factor to the growth of cool-season, and particularly warm-season pasture species.

The agriculture of the Southern Piedmont has been profoundly influenced by industrial development with its opportunities for nonfarm employment. This has promoted low-labor agricultural enterprises and increased acreages of permanent pastures and expanded beef production. This area also supports a very large poultry industry — layers, broilers, and, to a lesser extent, turkeys. Many farmers have found that operations that include poultry, beef cattle, and limited row crop plantings have been profitable as well as enabling excellent use of land and climatic resources.

Burns *et al.* (1973) found that tall fescue pastures gave 94 kg calf weight gain and 24 kg cow weight gain over a grazing season from April 8 to September 15. Inclusion of ladino clover to constitute about 20% of the sward increased calf weight gains 29 kg/ha and cow weight gains 27 kg/ha. Gross *et al.* (1966) reported that tall fescue plus Coastal bermudagrass resulted in a longer grazing period and more animal days per acre than tall fescue-ladino clover, although average daily gains on the latter were superior to those on tall fescue plus Coastal bermudagrass.

Lance *et al.* (1973) compared winter and summer cow-calf systems in the Georgia Piedmont area, using common and Coastal bermudagrass permanent pastures and annual winter pastures of wheat (*Triticum aestivum* [L.]), oats (*Avena sativa* [L.]), and ryegrass (*Lolium multiflorum* Lam.). Average weaning weight was nearly equal for the two cow-calf systems (fall calving vs spring calving)—194 kg/calf for the winter system and 191 kg/calf for the summer system. These results indicated that ways of reducing land requirements of 0.81 to 1.21 ha per cow, as well as other costs such as hay feeding, were important aspects of beef production needing further research.

Wilkinson *et al.* (1968) found that tall fescue could be successfully sodseeded into Coastal bermudagrass and maintained by use of proper clipping height and N fertilization. Fribourg and Overton (1973) confirmed this compatibility of tall fescue and Coastal bermudagrass. The tall fescue component of the combination is encouraged by N fertilization and moderate grazing during the cool season, whereas the bermudagrass component is encouraged by N fertilization and close grazing during the warm season.

Van Keuren and Stuedemann (1976) reviewed the literature on tall fescue in production systems for breeding and lactating animals. The lack of data on cow-calf performance and the incidence of beef cow health problems on perennial grass pastures of Kentucky-31 tall fescue and Coastal bermudagrass prompted our investigation into the management of pastures containing these perennial grasses at the Southern Piedmont Conservation Research Center (33° 52′ N; 83° 26′ E). This report will present information on available forage, botanical composition, cow-weight changes, and calf production on six pasture systems.

[1]Contribution from Southern Piedmont Conservation Research Center, Watkinsville, GA 30677, Agricultural Research Service, USDA, in cooperation with the University of Georgia Agricultural Experiment Stations.

EXPERIMENTAL PROCEDURE

Three Kentucky-31 tall fescue pastures, two Coastal bermudagrass pastures, and one Coastal bermudagrass pasture interseeded with tall fescue were grazed with Angus cows from 1972 through 1975. The prevalent soil was Cecil sandy loam, a typic hapludult of the clayey, kaolinitic, thermic family. Slopes ranged from less than 2 to 15%. The three fescue pastures, stocked at 0.4 ha/cow, were fertilized at three N levels: high N (703, 794, 483, 0 kg/ha from broiler litter in 1972, 1973, 1974, 1975, respectively), moderate N (224 kg N/ha per year from NH_4NO_3), and low N (84 kg N in 1972 and 74 kg N/ha in 1973, 1974, and 1975, respectively, from NH_4NO_3). The low-N bermudagrass pastures were stocked at 0.81 ha/cow and the moderate at 0.4 ha/cow in 1972 and 0.27 in 1973, 1974, and 1975. The moderate- and low-N bermudagrass pastures were fertilized at 280 and 20 kg N/ha per year from NH_4NO_3, respectively. The bermudagrass pasture interseeded with tall fescue in 1968 was stocked at 0.4 ha/cow and fertilized at 156 kg N/ha per year from NH_4NO_3.

Broiler litter was applied to the fescue pasture in February, June, and August in 1972, in January, May, September, and December in 1973, and in August, September, and December in 1974. Dry matter inputs of broiler litter were 17062, 21770, and 12376 kg/ha in 1972, 1973, 1974, respectively. Potassium inputs from broiler litter were 314, 439, and 268 kg/ha in 1972, 1973, and 1974, respectively. The other pastures were fertilized with P and K whenever soil tests for these nutrients were less than "medium." Phosphorus and K requirements to maintain the "medium" soil test levels for the entire 1972–75 period were 41 kg/ha and 159 kg/ha, respectively, for the moderate-N-fertilized fescue and 123 and 157 kg/ha, respectively, for the low-N-fertilized fescue. The low-N-fertilized bermudagrass received 11 kg/ha of P, but no P or K were required for the other bermudagrass pastures. Lime was applied only when soil pH levels dropped below 5.5. The only pasture that required liming was the Coastal-fescue combination, which received one application of 2.24 metric tons/ha.

All cattle were managed similarly. A 90-day breeding season beginning in mid-April was used. Bulls were rotated at least twice during the breeding season. All open cows, as judged by rectal palpation, were routinely replaced with pregnant cows that had calved at least twice. Calf production was estimated by Georgia Beef Cattle Improvement Association procedures. Cows were weighed routinely at 6-week intervals throughout the 4-year period.

During periods of insufficient forage, cows grazing the high- and moderate-N-fertilized fescue received hay harvested from their respective pastures. No hay was harvested from the other four pastures. In 1972, cows grazing the low-N-fertilized fescue were fed bermudagrass hay during periods of insufficient forage. In subsequent years, they received tall fescue hay harvested from a field fertilized at the same rate as the pasture. Cows grazing the other three pasture systems received good quality bermudagrass hay during periods of insufficient forage.

Available forage was estimated on the high- and moderate-N fescue by harvesting forage above 2.5 cm with a sickle-bar mower, and from ground level to 2.5 cm with hand clippers within each mower strip for all four years. The samples were collected carefully to minimize contamination with soil, decomposing vegetation, and feces. Similar sampling procedures were initiated in July, 1972, for the low-N-fertilized fescue and in January, 1974, for the moderate- and low-N-fertilized Coastal bermudagrass and bermudagrass-tall fescue combinations. The available forage estimates were of total dry matter and were not separated into living, dead, or botanical components.

Botanical composition was estimated from the frequency with which 20 points 10.16 cm apart on a 203.2-cm bar came in contact with bermudagrass, fescue, clover, weeds, bare ground, feces, etc. All tabulations of botanical composition presented are confined to the four categories of bermudagrass, fescue, clover, and "other." Botanical composition was estimated 16 times between April, 1974, and February, 1976, with a minimum of 36 estimates per pasture made with the 20-point bar described previously. The results are presented as average percentages of the total for three periods of the year, i.e., observations made from October through February, from March through June, and from July through September. These periods correspond to the winter period, the spring flush growth period for fescue and clovers, and the period when bermudagrasses grow the most rapidly. Visual estimates of herbage height and botanical composition were also made monthly. Since those estimates generally agreed with the point method estimates, they are not reported.

During this 4-year period, several animal health studies were conducted with cattle grazing these pastures. Results concerning grass tetany, fat necrosis, and nitrate poisoning are reported in more detail in Stuedemann *et al.* (1975) and nematode and coccidia parasitism are presented in Ciordia *et al.* (1976). Results for mineral element concentrations in forage from the high- and moderate-N-fertilized fescue are also presented in Stuedemann *et al.* (1975).

RESULTS AND DISCUSSION

Pasture species composition and forage availability. The high-N-fertilized fescue pasture was nearly pure fescue, with small areas of common bermuda-

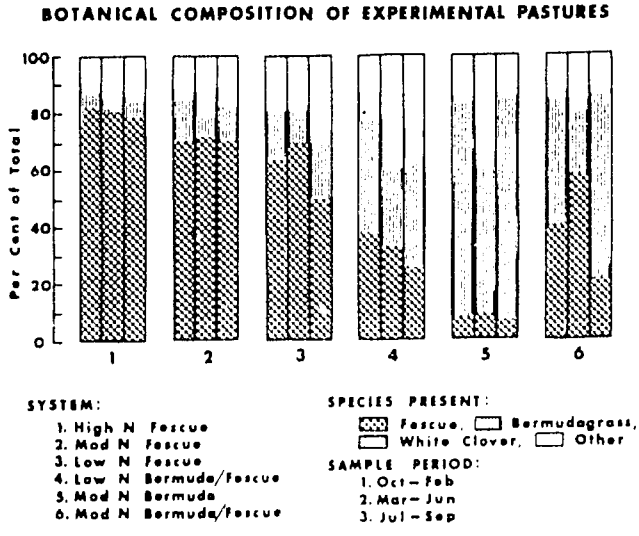

Figure 1. Botanical composition of southern Piedmont cow-calf pasture systems (each group of three bars represents results from sample periods 1, 2, and 3, respectively).

grass near fence rows (Fig. 1). The other category was predominantly bare ground and feces. Percentage of common bermudagrass and legumes, mostly wild white clover, was slightly higher in the moderate-N-fertilized fescue pasture. The most obvious weed in the high-N fescue (fertilized with broiler litter) was Spiny amaranth (*Amaranthus spinosus* L.); on the moderate-N fescue, horsenettle (*Solanum carolinense* L.) was also apparent. On the low-N-fertilized fescue pasture, common bermudagrass, bitter sneezeweed (*Helenium amarum*) (Ratin.) H. Rock and horsenettle, and in later years, Canada thistle (*Cirsium arvense* [L.] Scop.), dog fennel (*Eupatorium capillifolium* [Lam.] Small), and dallisgrass were apparent weed problems. Little or no bitter sneezeweed was observed in the high-N-fertilized fescue pasture until broiler litter fertilization was stopped in December, 1974. Very little legume was present in the low-N-fertilized fescue, although common lespedeza (*Lespedeza striata* Thumb., H&A), and white clover were observed.

The moderate-N Coastal bermudagrass pasture was predominantly bermudagrass during July through February, but many annual cool-season grasses and weeds appeared during March to June. Species represented were Carolina geranium (*Geranium carolinianum* L.), weedy grass annuals such as little barley (*Hordeum pusillum* Nutt.), annual bluegrass (*Poa annua* L.) and various other cool-season weeds. The low-N bermudagrass pasture was actually a Bermuda grass-fescue-clover mixture, appearing in a ratio over the last two years of 40-40-20 (by the point method). All the weeds previously mentioned were present in the low-N-fertilized Coastal bermudagrass pasture. Roughly 50% of the bermudagrass in this pasture was common bermudagrass.

The Coastal bermudagrass pasture interseeded with fescue contained the most fescue from March through June and the least from July through September. Visual estimates ranged from as little as 6% fescue in July to 75% fescue in April. Bermudagrass reached its peak in the July through September period, and was dormant from November to late April.

Crabgrass (*Digitaria sanguinalis* [L.] Scop.) was present during July and August in all pastures except the high-N fescue and moderate-N bermudagrass. Apparently, it was grazed as readily as the predominant pasture species.

Available forage above the 2.5-cm height was greatest in the high-N fescue and moderate-N Coastal bermudagrass (Fig. 2). Available forage above 2.5 cm was greatest during April through September on the high- and moderate-N fertilized fescue. Rather large amounts of forage available for grazing accumulated on the moderate- and low-N bermudagrass and the bermudagrass interseeded with fescue from July through frost. After frost, much of the bermudagrass remained on the pasture until March. The amount of forage in the 0- to 2.5-cm layer was fairly constant for the three bermudagrass pastures, but varied considerably on the three fescue pastures (Fig. 2). The moderate-N bermudagrass pasture contained more forage in the 0- to 2.5-cm layer at all times than was available on the low-N fescue. Very little herbage above 2.5 cm was ever present on the low-N fescue, although the maximum amount of forage was present, generally, during July through October. However, this was a period of reduced cow-calf performance because the forage available for grazing was of lower quality. Much of the available forage was refused forage around dung and weeds. Similar observations can be made for quality of Coastal bermudagrass pastures, in that poor-quality, stemmy material made up the bulk of the available forage on bermudagrass pastures from September to February. From mid-February through April, volunteer winter annual grasses and weeds contributed to forage available for grazing.

In only one pasture system, the low-N fescue, was the quantity of forage considered insufficient to prevent soil erosion. Barnett *et al.* (1972) concluded that heavy utilization of tall fescue forage through close grazing was as effective in controlling soil erosion as allowing the grass to reach a height of 7.5 cm or more. The low-N-fertilized pasture reached a maximum average height of 7.5 cm over the 1974, 1975 period, whereas the tall fescue fertilized with broiler litter fertilization reached a maximum average height of 29 cm.

The closely grazed low-N fescue had less than 56 kg/ha available forage above 2.5 cm during seven months of the year and less than 560 kg/ha of total

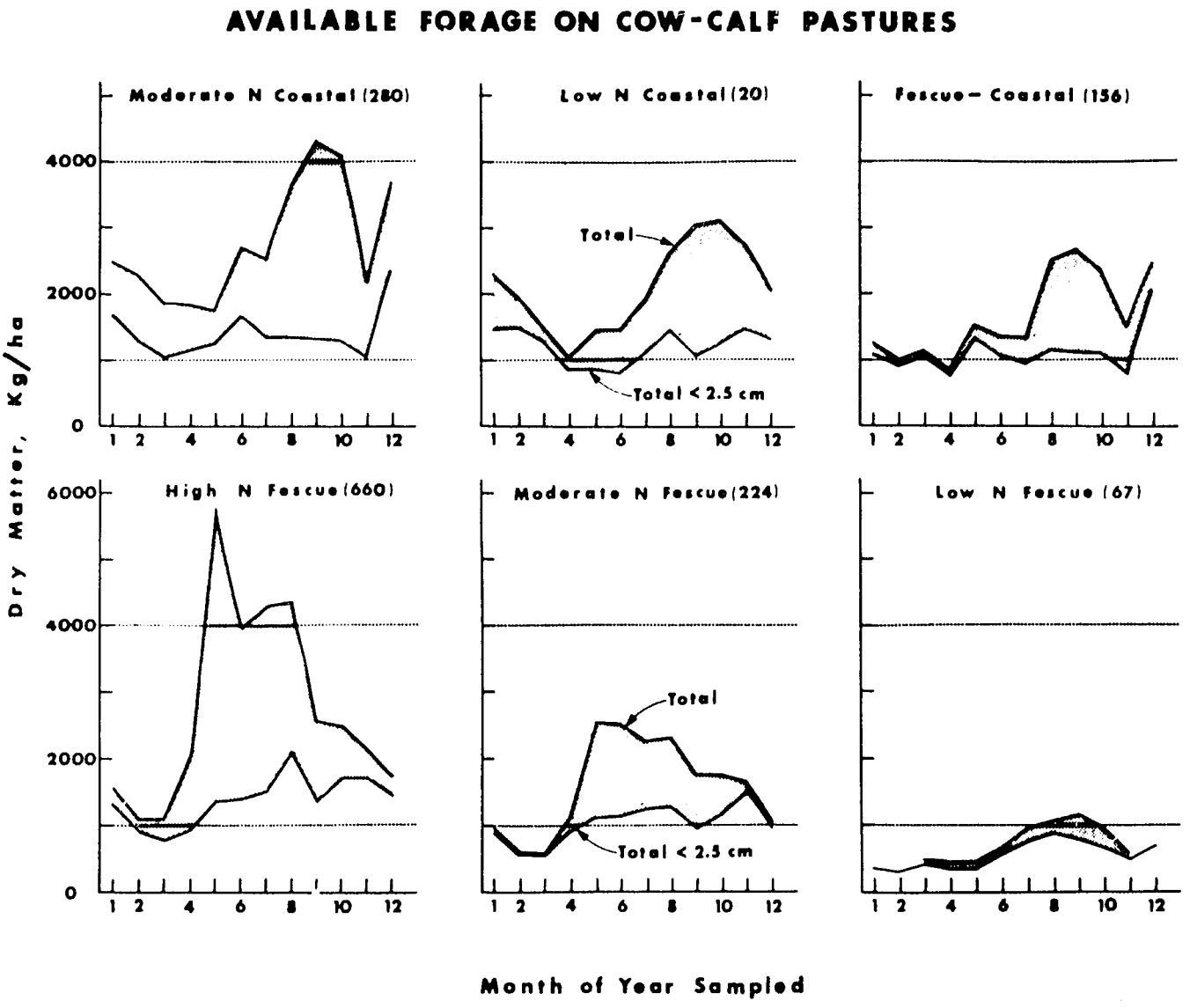

Figure 2. Available forage of southern Piedmont cow-calf pasture systems partitioned into that below 2.5 cm, and total by month of year sampled.

available forage for six months of the year. There was little evidence for accelerated soil erosion in any of the pasture systems.

Nitrogen fertilization increased available forage the most during the season of favorable growth of both tall fescue and Coastal bermudagrass. The increases in available forage at other seasons were less in absolute terms, but were important in relative terms. For example, in January the high-N-fertilized fescue had an average of 1 549 kg/ha dry matter, the moderate-N-fertilized tall fescue an average of 906 kg/ha, and the low-N-fertilized tall fescue an average of 391 kg/ha. In May, these available forage averages were 5 756, 2 852, and 437 kg/ha for the high-, moderate-, and low-N fertilized tall fescue, respectively. These results emphasize the importance of defining forage growth rate potential with each season and using fertilizer N to maximize growth potential during seasons when available forage is naturally lower. The higher rates of N fertilization produced more forage than was utilized at the stocking rates employed.

Cow-Calf Performance and Production. Individual calf weight was highest on the low-N Coastal bermudagrass pasture and lowest on the low-N tall fescue pasture (Table 1). There was a 23 kg/head difference in adjusted 205-day weights between these two pasture systems. Adjusted calf weights differed by only 5 kg among the high-, moderate-, or low-N tall fescue pastures. Since the tall fescue pastures were all stocked at the same rate, adjusted calf weights produced per ha varied little. The Coastal

TABLE 1. Weaned calf performance and production as affected by cow-calf pasture system, 1972–75

Pasture System	N Level	Stocking Rate	Cows/ Herd	Adjusted 205-day Weight	Adjusted Calf Production
	kg/ha	ha/cow	No.	kg/calf	kg/ha
Low N, tall fescue	77[a]	0.41[a]	16	162	380
Moderate N, tall fescue	224	0.40	24	167	376
High N, tall fescue	660[b]	0.40	21	165	372
Low N, bermudagrass	20	0.81	23	185	225
Moderate N, bermudagrass	280	0.30[c]	18	172	576
Bermudagrass-tall fescue	156	0.40	24	178	433

[a]Nitrogen fertilization with NH_4NO_3 was 84 kg/ha in 1972 and 74 kg/ha in 1973, 1974, and 1975, respectively. Stocking rate was 0.43 ha/cow in 1972 and 0.40 ha/cow during 1973, 1974, and 1975.

[b]Nitrogen fertilization from broiler litter was 703, 794, and 483 kg/ha for 1972, 1973, and 1974, respectively. No litter or fertilizer was applied in 1975.

[c]The stocking rate was 0.40 ha/cow during 1972 and 0.27 ha/cow during 1973, 1974, and 1975.

bermudagrass pasture interseeded with tall fescue produced more beef per ha than did any of the other pastures except the moderate-N-fertilized Coastal bermudagrass stocked at the higher rate. The low-N-fertilized Coastal bermudagrass pasture produced the lowest amount of beef per ha because of the low stocking rate.

Mean adjusted calf weights on the low-N-fertilized fescue pasture for 1972, 1973, 1974, and 1975 were 458, 410, 318, and 335 kg/ha, respectively. Cow weight patterns and internal parasite data (Ciordia *et al.*, 1976) indicate that either a cow/calf nutrition effect, parasitism in calves, or an interaction between the two caused the lower calf weights during the last three years of the study. Calf weights on the moderate- and high-N fertilized pastures tended to remain fairly constant over the 4-year period (data not shown). The Coastal bermudagrass pasture previously interseeded with tall fescue, fertilized with 156 kg N/ha, and stocked at 0.4 ha/cow was considered most effective in producing calf weight per unit of land and N.

The cows grazing the high-N tall fescue were the heaviest, required the least amount of hay, and lost about 81 kg of weight (Table 2). The cows grazing the low-N fertilized fescue were the lightest, required the most amount of hay, and underwent about the same weight loss. Cows grazing the moderate-N-fertilized Coastal bermudagrass were fed 51 kg less hay than those grazing low-N-fertilized fescue. More hay was harvested from the high- and moderate-N-fertilized fescue pastures than was later refed to cows on these pastures.

Conception rates (90-day exposure) were lowest

TABLE 2. Cow performance as affected by cow-calf pasture system, 1972–75

Pasture System	N Level	Stocking Rate	Hay Fed	Minimum[a] Cow wt.	Maximum[a] Cow wt.	Average[a] Cow wt.	Conception Rate (90-day Exposure)
	kg/ha	ha/cow	kg/cow	kg/cow	kg/cow	kg/cow	%
Low N, tall fescue[b]	77	0.41	416	339	411	375	85.0
Moderate N, tall fescue	224	0.40	34[c]	372	448	407	75.0
High N, tall fescue	660	0.40	16[c]	401	482	429	78.6
Low N, bermudagrass	20	0.81	122	338	424	380	91.3
Moderate N, bermudagrass	280	0.30	365	333	414	372	82.3
Bermudagrass-tall fescue	156	0.40	180	344	435	391	80.2

[a]Minimum and maximum cow weights are the means of individual cow weight minima and maxima for cows on the pasture the entire year. Average cow weights are the means of all cows on the pasture the entire year and are averaged across all weigh dates.

[b]Footnotes with respect to N fertilization and stocking rate from Table 1 also apply to Table 2.

[c]931 kg/ha of cured hay was harvested annually from the high N tall fescue and 511 kg/ha of cured hay from the moderate-N fertilized fescue.

on the pasture systems receiving the higher N rates and best on the low-N bermudagrass. Differences in conception rates were not statistically significant at the 5% level when only 1972–75 data were considered. However, when the 1972–76 observations of conception rate were analyzed, pasture systems effects on conception rate were statistically significant at the 5% level by F test. A statistically significant trend toward lower conception rates at higher N rates on tall fescue was noted when five years of data were pooled (Stuedemann, J. A., unpublished data, 1976).

Beef cow health problems of grass tetany, fat necrosis, nitrate poisoning, and fescue toxicity also were studied on the three tall fescue-based pastures from 1972–75 (Stuedemann *et al.*, 1975). On the high-N fescue pasture, there were 13 grass tetany cases that resulted in seven deaths among 45 cows not supplemented with Mg. On the moderate-N fescue pastures, there were seven tetany cases that resulted in five deaths among 48 cows not supplemented with Mg. There were no grass tetany cases on the low-N fescue pastures. Cows grazing the other three pasture systems received Mg supplementation in the mineral box during January through April, and there were no cases of grass tetany in these pastures.

The incidence of fat necrosis (hard fat) as determined by rectal palpation among cows grazing the various fescue pastures increased with increasing levels of N fertilization (Stuedemann *et al.*, 1975). No fat necrosis was detected by rectal palpation of cows grazing the predominantly bermudagrass pastures. Concentrations of NO_3-N of 3 300 Mg/g had been reported earlier in the tall fescue forage fertilized with broiler litter (high N). No direct evidence of an effect of these NO_3-N levels on animal health was observed.

In 1973 and 1974, two calves were slaughtered from each pasture at weaning to obtain worm counts. Average number of worms per calf for 1973 and 1974 were 6 193, 17 773, and 37 197 for the high-, moderate-, and low-N fertilized fescue pastures, respectively. The level of gastro-intestinal parasitism seemed more related to closeness of grazing than to the level of N fertilization (Stuedemann *et al.*, 1975; Ciordia *et al.*, 1976).

Problems possibly associated with fescue toxicity were incurred on the high- and moderate-N fertilized fescue pastures. These problems, and some alkaloid analyses of herbage from the high- and moderate-N fertilized pastures, are described by Stuedemann *et al.* (1975) and publications cited therein. The overall appearance, i.e., haircoat and alertness of cows was consistently poorer on the high- and moderate-N fescue than on the other four pastures.

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133.
Pasture Performance of Beef Cows and Calves Grazing Orchardgrass, Tall Fescue, and Tall Fescue-Legume Herbage*

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The relative merits of tall fescue (*Festuca arundinacea* Schreb.), tall fescue-legume and orchardgrass (*Dactylis glomerata* L.) pastures have been previously investigated (Peterson *et al.*, 1962; High *et al.*, 1965; Burns *et al.*, 1973). In these and in most other pasture evaluation studies the tester animals have been young, growing animals. The results obtained with growing animals may not be applicable to situations where the grazing animals are cows and their nursing calves. The herbage quality of a pasture is presumably reflected in the daily gain of the grazing animals and in the case of growing animals an increase in gain results in an increase in salable product. In cow and calf production, however, the amount of salable product depends on the size and number of calves produced. The cow accounts for the major portion of the herbage consumed but her weight gain is of minor importance as long as rebreeding is not impaired. Herbage quality in these situations may be reflected in cow weight gain, calf weight gain, and cow conception percentage. Herbage quality may have relatively little influence on calf gains early in the grazing season when the calves consume only a small amount of herbage. On the other hand, calf gains may be greatly influenced by herbage quality later in the grazing season when the calves are large enough to consume a considerable amount of herbage and milk production of the cows has declined.

Burns *et al.* (1973) compared the performance of cows and calves grazing tall fescue and tall fescue-ladino clover (*Trifolium repens*) pastures during the early and latter part of two grazing seasons. Cow and calf gains were greater on tall fescue-legume pastures than on tall fescue pastures during the entire grazing season. Calf gains were influenced more by the legumes during the late part of the grazing season than during the early part of the season. No animal reproduction problems were encountered.

The present research was conducted to determine the relative performance of cows and calves when grazing orchardgrass, tall fescue, and tall fescue-legume pastures under southern Indiana conditions. The specific objectives were to determine the effect of pasture species on the average daily gain of cows and calves and the conception percentage of cows.

MATERIALS AND METHODS

Established stands of orchardgrass, tall fescue, and tall fescue-legumes were grazed during the 1972, 1973 and 1974 grazing seasons at the Southern Indiana Purdue Agricultural Center in Dubois County. This Center is located at 38.4° N latitude and 86.7° W longitude, at an elevation of approximately 65 m. Predominant soils are Zanesville (fine, silty, mesic, typic fragiudulf) and Tilsit (fine, silty, mixed, mesic, typic fragiudulf) with 6–12% slopes. The region receives approximately 110 cm rainfall yearly and average temperature ranges from −2 C in winter to +24 C in summer.

The legumes in the tall fescue-legume pastures consisted primarily of ladino clover and red clover (*Trifolium pratense*). All pastures were fertilized with P and K at a maintenance level based on soil test recommendations. The tall fescue and orchardgrass pastures each received 112 kg nitrogen/ha prior to the start of each grazing season. Each treatment was replicated twice on 10-ha pastures in a completely random design. During the 1972 grazing season, 19 cows were grazed on each pasture, however, 11 of them were non-lactating pregnant cows. Eight cows were nursing calves. Each pasture was grazed with 19 cows and their calves during 1973 and 1974. The grazing season began on April 20 and ended on October 6 of each year.

The stocking rate was selected to approximately match anticipated summer forage production. Each pasture was subdivided and the animals were restricted to only part of the pasture during the periods when forage production exceeded animal consumption. The excess production was then harvested as hay. During the latter part of the grazing season the animals were allowed to graze the entire pasture on a rotational basis. All animals were weighed at the start of the grazing season and at 28-day intervals. Cows were bred during a 60-day breeding period beginning on May 12 of each year. Pregnancy was diagnosed at the end of each grazing season and

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non-pregnant cows were removed from the experiment.

All cows were wintered in one group on hay and fall-saved forage. Between calving time and the start of the grazing season, the cows received a ration of corn silage and grass hay. The cows and their calves were randomly assigned to the pasture treatments at the start of each grazing season.

Four cages were placed in each of the tall fescue-legume pastures during the second year of the experiment. Clippings were made from the cages on three dates and the percentage of legume in the grass-legume pastures estimated on a dry weight basis.

The animal weight data were analyzed statistically using analysis of variance techniques. The significance of differences between means was determined using Newman-Keuls Test (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Botanical Composition

The proportion of legumes in the tall fescue-legume pastures increased from 12.2% on May 23 to 39.8 and 35.8% on June 20 and July 12, respectively (Table 1). These data indicate that the legumes in the tall fescue-legume pasture constituted a considerable portion of the grazable herbage during June and July when animal gains on tall fescue pastures are often low. The increase in the proportion of legume during the middle and latter part of the grazing may partly explain the greater animal gains often reported with tall fescue-legume pastures as compared to tall fescue pastures (Burns *et al.*, 1973).

TABLE 1. Percentage legume in tall fescue-legume pastures during the grazing season (dry weight basis)

	Date			
Pasture Replication	May 23	June 20	July 12	Average
1	14.4	37.2	44.6	32.1
2	10.3	42.4	27.0	26.6
Average	12.2	39.8	35.8	29.4

Animal Gains

Calf gains averaged 0.81, 0.58, and 0.83 kg/day for the orchardgrass, tall fescue, and tall fescue-legume pastures, respectively (Table 2). The daily gains were consistent among pasture treatments during each year of the experiment. The differences in calf gains between the tall fescue pastures and the tall fescue-legume pastures were similar to those reported by Burns *et al.* (1973) when tall fescue and tall fescue-ladino clover were grazed. Calf daily gain differences resulted in nearly a 40 kg difference in calf weight at weaning.

TABLE 2. Average daily gains (kg/day) of lactating cows and calves and conception percentage of cows grazing orchardgrass, tall fescue, and tall fescue-legume pastures

	1972	1973	1974	Average
Calf gains (kg/day)				
Orchardgrass	92a	.74a	.76a	.81a
Tall fescue	.67b	.53b	.55b	.58b
Tall fescue-legume	.93a	.76a	.79a	.83a
$S_{\bar{x}}$	.033	.027	.034	.018
Cow gains (kg/day)				
Orchardgrass	.29a	.16a	.33a*	.26a
Tall fescue	.08b	−.10b	.04b	.01b
Tall fescue-legume	.33a	.11a	.34a	.26a
$S_{\bar{x}}$	.064	.063	.085	.041
Cow Conception (%)				
Orchardgrass	95	86	89	90
Tall fescue	83	77	54	71
Tall fescue-legume	98	94	84	92

Means in a column within animal type followed by a common letter do not differ significantly at .05 level of probability using Newman Keul's Test.

* Denotes significance at .10 level of probability.

Cow gains (Table 2) averaged 0.26, 0.01, and 0.26 kg/day for orchardgrass, tall fescue, and tall fescue-legume pastures. Cow gains were considerably more variable than calf gains. The gains obtained with orchardgrass and tall fescue-legume pastures were considered acceptable and compare favorably with those reported by Burns *et al.* On tall fescue pasture the cow gains were low and during the second year of the experiment the cows lost weight during the grazing season.

Conception Percentage

Cow conception percentage averaged 90, 71, and 92% for the orchardgrass, tall fescue, and tall fescue-legume pastures (Table 2). The considerable depression in conception percentage with tall fescue pastures is of great economic consequence. The reason for apparent decline in conception percentage on these pastures during each subsequent year of the experiment is not apparent since all animals were wintered in one group and randomly assigned to pasture treatments at the start of each grazing season. Therefore, nutritional carryover effects from year to year should have been minimal. The poor conception percentage of the cows on tall fescue pasture is probably related to their low weight gains. This difference in conception percentage between cows grazing tall fescue and those grazing tall fescue-legume pastures is not consistent with the report

TABLE 3. Monthly average daily gain (kg/day) of calves grazing orchardgrass, tall fescue, and tall fescue-legume pastures (3-year average)

Pasture	4/20-5/18	5/19-6/15	6/16-7/13	7/14-8/10	8/11-9/7	9/8-10/6	Season average
Orchardgrass	.88a	.70a	.90a	.78a	.83a	.74a	.81a
Tall fescue	.80b	.57b	.58b	.52b	.56b	.49b	.58b
Tall fescue-legume	.93a	.77a	.82a	.81a	.87a	.80a	.83a
$S_{\bar{x}}$	.025	.035	.043	.073	.036	.038	.018

Means in a column followed by a common postscript do not differ significantly at .05 level of probability using Newman-Keul's Test (Steel and Torrie, 1960).

of Burns *et al.* (1973). However, other researchers (Wiltbank *et al.*, 1964) reported that conception percentage was greatly reduced when cows did not consume enough energy during the post-calving period to support body weight gain.

Seasonal Trends in Animal Gains

The average daily gain of the calves during each month of the grazing season is shown in Table 3. Calf gains on tall fescue pastures were significantly lower than those on orchardgrass or tall fescue-legume pastures during each month of the grazing season. The difference in daily gain between the calves grazing tall fescue and those grazing tall fescue-legume was .13 kg/day in May and the difference increased to .31 kg/day during August and September. These data suggest that the quality of the pasture had relatively less influence on the calf gains during the early portion of the grazing season when the calves were presumably consuming a relatively large amount of milk. During the latter part of the grazing season, when the calf gains were more dependent on herbage consumption, the difference in performance between animals on tall fescue and those on tall fescue-legume became greater. The increasing proportion of legume in the herbage as the season progressed (Table 1) may have helped maintain high calf gains on the tall fescue-legume pastures. Daily gains of animals grazing orchardgrass were similar to those grazing tall fescue-legume pastures during each month of the season.

The monthly daily gains of the lactating cows are shown in Table 4. The gains of cows grazing tall fescue pastures were somewhat lower than those of cows grazing tall fescue-legume pastures during each month of the season. However, the difference in gain was not statistically significant during the second, fourth and fifth months and significant at only the 10% level of probability during the third and last months of the grazing season.

The differences in cow and calf gains suggest that the animal performance problem associated with grazing tall fescue is a season-long problem and not confined simply to the mid-summer months, although animal gains on tall fescue may be relatively lowest during those months.

Lactating vs Non-Lactating Cows

During the first year of the experiment only part of the cows were lactating. The remaining cows on each pasture were dry pregnant cows. The performance of these two groups is shown in Table 5. Tall fescue resulted in significantly lower average daily gains than either orchardgrass or tall fescue-legume pastures for each group of cows. The daily gain of non-lactating cows averaged 0.21 kg/day more

TABLE 4. Monthly average daily gain (kg/day) of lactating cows grazing orchardgrass, tall fescue, and tall fescue-legume pastures (3-year average)

Pasture	4/20-5/18	5/19-6/15	6/16-7/13	7/14-8/10	8/11-9/7	9/8-10/6	Season Average
Orchardgrass	.66a	.37a	.17a*	.14a	.20a	.03a*	.26a
Tall fescue	.12b	.38a	−.20b	−.06a	.01a	−.18b	.01b
Tall fescue-legume	.90a	.47a	−.19b	.10a	.21a	.09a	.26a
$S_{\bar{x}}$	.080	.147	.114	.082	.091	.073	.041

Means in a column followed by a common postscript do not differ significantly at .05 level of probability using Newman-Keul's Test.

*Denotes significance at 10% level of probability using Newman-Keul's Test.

TABLE 5. Average daily gain (kg/day) of lactating and non-lactating cows grazing orchardgrass, tall fascue, and tall fescue-legume pastures during 1972

Pasture	Lactating cows	Non-lactating cows	Weighted* average
Orchardgrass	.29a	.54a	.43a
Tall fescue	.08b	.27b	.19b
Tall fescue-legume	.33a	.51a	.43a
Average	.23	.44	.35
S_x	.064	.064	.045

*Weighted according to number of lactating and non-lactating cows.

Means followed by a common letter do not differ significantly at .05 level of probability using Newman-Keul's Test.

than that of lactating cows, however, the trend with pasture type was similar.

These results indicate that cow and calf gains on tall fescue pastures can be greatly improved by the incorporation of legumes into the pasture. The animal production on orchardgrass pastures was similar to that of tall fescue-legume pastures. The reason for the difference between orchardgrass and tall fescue is not apparent. However, tall fescue is known to contain a number of alkaloids (Bush *et al.*, 1972; Grenz, 1975; Gentry *et al.*, 1969). These alkaloids have been shown to affect the digestibility of the grass and may influence animal acceptability and intake. Nitrogen fertilization increases the concentration of these alkaloids in tall fescue and thus may further accentuate the animal performance problem on tall fescue pastures.

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DISCUSSION

J. Washko (Pennsylvania, USA). Dr. Lechtenberg, how much nitrogen were you applying to these grasses?

Lechtenberg. The grass pastures received 112 kg of nitrogen per ha the spring of each year—one application in early spring, early April or late March, somewhere around there.

Washko. Well, I was just wondering because it looked like the orchardgrass got the same as the others.

Lechtenberg. Orchardgrass and the tall fescue received the same amount of nitrogen. The fescue-legume received no nitrogen, and all the pastures received about 60 kg P_2O_5 and 120 kg of K_2O to the acre.

W. Moser (Oregon, USA). Have you done any work on protein content of the forages that are involved? In other words, tall fescue vs tall fescue-clover vs orchardgrass on protein content?

Lechtenberg. During this study we did not. In some previous work we have assessed the protein content and particularly tall fescue during the grazing season and as long as we're sampling green material we have seldom gone below about 11%.

Moser. What is the tall fescue-legume running? What is the orchardgrass running?

Lechtenberg. The orchardgrass in similar studies would run 10 to 12% also. It would be very comparable under similar fertility situations. I hesitate to say on the tall fescue-legume; it's going to depend on how much legume you happen to have in it. We did not analyze it. I'm guessing that it would probably run 13 to 15— under situations where we had 30 or more percent clover.

Moser. Did you utilize most of the pasture or were the animals selective in what they ate?

Lechtenberg. During the first two months of the grazing season we did have very uniform grazing of the material where the animals were confined. We had them confined to half of the pastures; they did a good job of taking the material down quite evenly. Of course on the other half of the pasture then we harvested hay so that regrowth was fairly evenly consumed and we feel that we had pretty uniform and even utilization of the material that was available.

We guessed at the stocking rate initially and we did quite well, I think, until we got down into the late part of the grazing season and particularly during two years of this study, we had a quite dry late summer and fall and our grazing pressure got fairly high during late October. If you recall, the calf weight gains tended to tail off during the last month of the grazing season when, based on the nutritional

characteristics of the grass, you might have expected that they would go up. I think that's because we were probably overestimating the grazing capacity a little bit.

K. Inskeep (West Virginia, USA). On these conception rates for 60-day periods that you've reported, and I assume the ones that Dr. Wilkinson reported are similar, these are really pregnancy rates which result from a combination of variables over that total period. I'm wondering if any of you can dissect that a bit. How much of it is due to a lengthened postpartum interval and how much is due to conception rate *per se* in cows that do come in heat and are bred? Do you know which of these components of reproduction is really important?

Lechtenberg. I understand your question, but I would have to say that I can't answer because we have not really tried to assess any differences in calving dates as a result of the treatment or the pasture treatments that these cows were on.

Inskeep. As a reproductive physiologist, I would like to ask those of you working in the agronomic area to keep in mind that reproduction has several components. I think these components are something that you need to get a better measure of in future work.

Lechtenberg. I agree; I think that's a very good point.

Wilkinson (Georgia, USA). I would just like to comment—ours is a 90-day breeding season. We use three different bulls. What is it you're referring to as increased postpartum interval?

Inskeep. The postpartum interval is the interval from calving until the back into estrus so that she can be bred as opposed to conception rate, which is the percentage of cows that conceive of those that are bred.

Wilkinson. We did not see an increase in calving date as you might expect and we were watching it because we were studying these cows for grass tetany and calving date is pretty critical for grass tetany.

J. Baylor (Pennsylvania, USA). In your studies these animals were continuously on one of the three species. Is that right?

Lechtenberg. No, they were not. They were on one of the three pasture species during the pasture grazing season only. They were all wintered together as a group on some fall-saved aftermath and then at calving time about half corn silage and half hay and then they were reallocated to the pasture treatment at the beginning of each season and allotment was stratified across previous pasture treatment.

Baylor. Then based on your data, what would you assume to be the place of tall fescue as a component of a total pasture system?

Lechtenberg. Anything but during the summertime.

134.
Management Systems for Sheep and Lamb Production on Hill Land

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The University of Illinois Dixon Springs Agricultural Center is located at 37° 30′ N lat. and 88° 40′ W long. on the southeast watershed of the Ozark uplift on 2023 ha of Shawnee National Forestland. The unglaciated soils, predominately Grantsburg, Zanesville and Millstone silt loams, are sloping (land capability Class IV and VI with a pH of 5.5 to 5.8) and subject to severe erosion. The growing season is approximately 200 days. The average annual precipitation of 114 cm is 50% more than that received in the grain belt of central and northern Illinois; the excess falls during the winter and early spring.

The research area was established on eroded, unproductive abandoned land, and the decision was reached that emphasis would be placed on the production of forages. Fertility deficiences—principally calcium and phosphorus—were corrected and adapted grasses and legumes were established. Forage production was increased significantly to produce 336 to 560 kg of animal gain per ha per year on many areas and a high of 764 kg (Cate, 1951) on one well-managed plot with sheep and cattle grazing together.

This increased forage production with increased carrying capacity made effective grazing management more difficult. The number of lambs with adequate finish for market produced per ha did not always keep pace with the improved yields of forages. The selective grazing habits of the sheep often resulted in poor forage utilization, when considered in terms of total production, and may have reduced the population of the more palatable plant species. Van Keuren and Heinemann (1958) reported that ladino clover in a mixture with orchardgrass was selectively grazed to a point of stand reduction. Grazing studies at the Dixon Springs Center indicated that this was equally true of other legumes in a mixture with some of the more vigorously growing grasses, such as the tall fescues, and resulted in a recommendation that pure stands of grasses or legumes be used for pastures grazed exclusively by sheep.

The efficient grazing of these more productive pastures required an increase in animal units per ha and often resulted in forage wastage through trampling and contamination. High stocking rates usually result in greater total animal gains from an area while at low stocking rates higher individual gains occur.

Heavy stocking rates, such as those made possible by increased forage production, in our warm, humid environment encouraged the rapid buildup of internal parasites until usual grazing management and available anthelmintics did not provide adequate control to allow for high levels of performance in growing or fattening lambs grazed with ewes. Admittedly, Cameron and Gibbs (1966) reported little or no relationship between stocking rates and the level of parasitism, but this work was with weaned lambs not grazed with an adult population. Shaw and Muth (1946) and Moles *et al.* (1958) reported that irrigation and increased fertilization resulted in greater carrying capacity but also with higher mortality due to increased parasitism. Mansfield *et al.* (1967) reported that lambs could be produced free of gastrointestinal parasites by management alone. McKibben *et al.* (1959) reported an increase of 71% in carrying capacity of irrigated pastures grazed by yearling steers as compared to non-irrigated pastures, but the increase in animal gain was only 46%. Since this work reported success in maintaining palatable forage species such as ladino in a pasture mixture at a 23% level after seven years, it would appear that irrigation may have potential if the forage is grazed by early weaned lambs. The lambs would need additional concentrates to furnish some of the energy required to reach market grade.

Even though forage yields had been increased, the problems associated with parasitism and predation prompted the initiation of research in 1959 to study various traditional as well as new systems of lamb production. The systems were studied over a period of years and the initial systems are presented in Table 1.

In all studies, native spring lambs sired by Suffolk and Hampshire rams were randomly assigned to outcome groups by sex, age and type of birth. The groups were then randomly assigned to the treatments listed in Table 1. The ration in Table 2 was fed in a creep to all lambs before going on trial and to lambs in those management systems in which lambs were fed.

Ewes and lambs were confined to drylot until

TABLE 1. Systems of managing ewes and lambs

System 1	—Lambs weaned, self-fed on legume pasture
System 2	—Lambs self-fed in drylot, ewes on legume pasture during the day and returned to the lambs during the night (In-and-Out)
System 3	—Lambs weaned and self-fed in drylot
System 4	—Lambs and ewes on legume pasture, lambs creep-fed
System 5	—Lambs and ewes on legume pasture, no creep
System 6	—Lambs and ewes on orchardgrass* pasture, no creep
System 7	—Lambs and ewes on orchardgrass* pasture, lambs creep-fed
System 8	—Lambs weaned, self-fed on grass pasture
System 9	—Lambs self-fed in drylot, ewes on orchardgrass pasture during the day and returned to the lambs during the night (In-and-Out)
System 10	—Approximately half of the lambs in systems 4, 5, 6 and 7 were weaned and self-fed in drylot after 28 days on pasture with their dams
System 11	—Ewes separated from the lambs daily, grazed on fescue pasture and returned to the lambs at night. Lambs confined to shelter with self-feeder
System 12	—Ewes managed as outlined above, lambs given access to high quality legume pasture in addition to self-feeder
System 13	—Ewes separated daily, grazed on legume pasture, returned to the lambs at night, lambs managed as in System 12

*Orchardgrass pastures received one spring application of 200 pounds ammonium nitrate.

TABLE 2. Lamb ration

Ingredient	Amount (kg)
Ground shelled corn	272.2
Ground mixed hay	113.4
Soybean meal (44% C.P.)	68.0
Bonemeal	4.5
Feeding grade limestone	4.5
Salt	2.3
Premix	†

†2 205 I.U. Vitamin A per kg of ration.
441 I.U. Vitamin D_3 per kg of ration.
22 mcg Vitamin B_{12} activity per kg.
22 mcg terramycin activity per kg.

placed on the various treatments. While in drylot, all ewes were drenched with 35 g of fine particle phenothiazine-lead arsenate. The ewes and their lambs were individually weighed initially and at approximately 28-day intervals until lambs were marketed or the study terminated.

Fecal samples were collected each weigh day from five ewes and five lambs in each lot; fecal donors had been randomly selected at the beginning of the study. *Strongyloid* nematode egg counts were made by the Whitlock flotation method (Whitlock, 1948).

Fecal samples from the early-weaned lambs did not reveal *Strongyloid* nematode eggs until June 22 and then in very small numbers (Table 3). Parasite infestation as measured by fecal egg count was also very low for lambs that remained in drylot but were with the ewes in drylot at night (in-and-out system).

TABLE 3. Evaluation of gastrointestinal nematode infestation of ewes and lambs under various systems of management in 1960

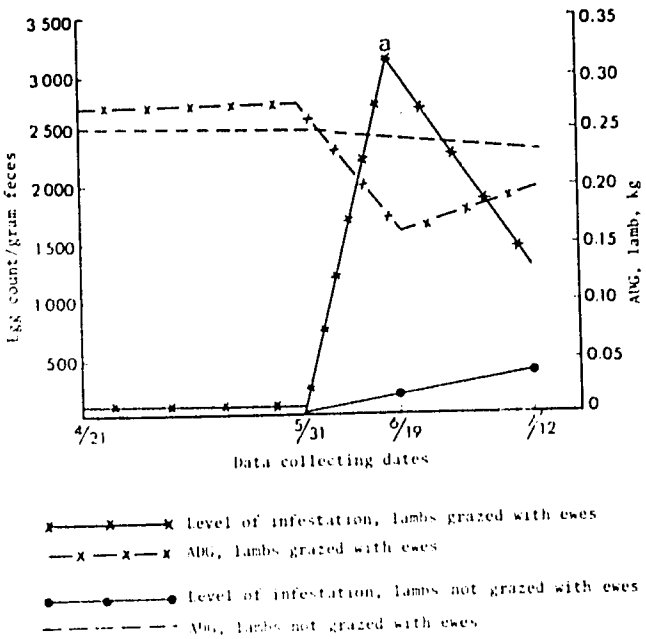
System		Average EPG*			
		Dates of Fecal Sampling			
		4-18	5-16	6-22	7-12
No Creep	Lambs	0	0	5 802	653
	Ewes	7 465	5 711	25	0
Creep	Lambs	195	20	1 632	475
	Ewes	2 060	3 682	544	563
Weaned (4/18)	Lambs	0	0	17	35
In-and-out	Lambs	0	75	300	1 838
	Ewes	2 265	2 067	420	120
Weaned (5/16)	Lambs		0	1 350	25

*Eggs per gram of feces by Whitlock (Whitlock, 1948) flotation method. To shorten this table, lambs were grouped according to the feeding program disregarding the type of pasture.

Fecal samples collected on June 22 from lambs pastured with their mothers showed a rapid and serious increase in internal parasite infestation. Figure 1 illustrates the interaction of parasite infestation and lamb gains. These data, although from only one year, are similar to data collected for three years on studies of similar systems of management and provide evidence that internal parasites can be controlled effectively without anthemintics where lambs are not permitted to graze with an infected adult population.

Although overall gains of lambs on nitrated grass were generally as good as those by lambs on legume-grass pasture (Table 4), this relationship was largely the result of superior gains of lambs on nitrated grass from mid-April to mid-June. Subsequently, during the critical finishing period from mid-June through July, lamb gains on nitrated orchardgrass decreased below those for lambs on legume-grass pastures; thus, more lambs of market grade and weight were produced from the legume-grass pasture.

Creep feed on pasture did not consistently increase gains but did increase the percentage of lambs reaching market weight and grade. The in-and-out system consistently produced the most rapid gains and the most lambs reaching market weight and grade.



a = Lambs grazed with ewes were drenched on June 19 with fine particle phenothiazine-lead arsenate mixture.
Figure 1. Parasite level and lamb performance.

Each of the following variations of the in-and-out system were studied for two years.

System 11. Ewes separated from the lambs daily, grazed on fescue pasture and returned to the lambs at night. Lambs confined to shelter with self-feeder.

System 12. Ewes managed as outlined above, lambs given access to high-quality legume pasture in addition to self-feeder.

System 13. Ewes separated daily, grazed on legume pasture, returned to the lambs at night, lambs managed as in System 12.

In 1963, lambs allowed access to legume pasture gained more rapidly (22.7%) and required less concentrate per unit of gain (44.7%) than lambs confined to drylot (Table 5). In 1964, the lambs confined to shelter and self-fed gained more rapidly than the lambs with access to pasture in addition to being self-fed (14%), but the lambs with pasture available required less feed (16.8%). Both lots gained more rapidly than lambs handled in a similar manner in previous years. At least two factors contributed to this variation: (1) half the lambs were rams, and (2) the crude protein content of the diet was increased from 15 to 17% as indicated by the results reported by Hinds *et al.* (1964).

TABLE 4. The effect of four management systems on lamb gains, feed cost, death loss and lambs sold

Management System	1959 Nitrated Grass	1959 Legume Grass	1960 Nitrated Grass	1960 Legume Grass	1961 Nitrated Grass	1961 Legume Grass
1 ADG	.18	.18	.24	.17	.19	.23
% Sold	37.5	25.0	59.1	40.0	38.5	71.4
Feed/gain ratio	—	—	0	0	—	—
Death loss %	0	0	6.3	6.3	4.8	0
2 ADG	.21	.19	.24	.23	.19	.13
% Sold	75.0	31.3	55.0	63.6	66.6	71.4
Feed/gain ratio	†	†	.6	1.5	2.2	1.0
Death loss %	0	0	3.1	6.3	9.5	0
3 ADG	.20	.20	.19	.20	††	††
% Sold	50.0	46.9	47.0	72.0		
Feed/gain ratio	†	†	3.0	2.3		
Death loss %	3.1	6.2	0	0		
4 ADG	.24	.22	.26	.25	.25	.23
% Sold	62.5	59.4	84.4	87.5	83.0	80.0
Feed/gain ratio	†	†	4.3	4.2	4.6	5.3
Death loss %	6.2	0	6.3	0	2.4	0

†Data not available.

††System was not included in 1961. To shorten this table, lambs were grouped according to the feeding program disregarding the type of pasture.

Systems: 1—Lambs pastured with ewes, no creep 2—Lambs pastured with ewes + creep 3—Lambs weaned and self-fed on pasture 4—In-and-Out

TABLE 5. Feed and gain data for lambs managed under variations of in-and-out systems

	System 11		System 12		System 13
	1963	1964	1963	1964	1964
Average initial weight, kg	20.8	24.7	19.1	24.0	23.0
Average daily gain, kg					
4/24-5/22	.30	.38	.36	.33	.37
5/22-6/20	.23		.21		
5/22-6/10		.32		.24	.31
6/20-7/25	.18		.24		†
6/10-7/09		.25		.21	
Average	.22	.32	.27	.28	.34
kg feed per kg gain	4.11	3.63	2.84	3.02	2.89

†System 13 terminated 47 days on trial—data for 47 days.

In-and-out management produces a rapid-gaining, high-quality lamb. Allowing the lambs access to a high-quality legume forage reduced the concentrate feed needed to produce lambs of market weight and grade. The system adequately controlled internal parasites without anthelmintics. A major disadvantage is the labor requirement. The shepherd must be present twice daily. The time involved will vary with the operator, equipment, and size of the flock, but 30 minutes per day should be adequate for a flock of 40 ewes after they are trained.

Subsequent work has indicated that lambs weaned at eight to nine weeks of age and fed a high energy (75–90% concentrate) high protein (16–18%) diet gained as rapidly and efficiently as lambs managed in the in-and-out system with less labor. Thus, when feed grains are relatively cheap, labor is scarce and/or expensive, predator losses are high and the lamb producer is interested in developing an accelerated lambing system, early weaning and confinement feeding may be the most profitable management system.

Some operators of forage programs in hill land are limited in area and do not have sufficient ewe numbers to provide adequate income. Early weaning and confinement feeding could provide the opportunity to increase ewe numbers on a given area. Dr. J. B. Outhouse, Purdue University (personal communication), suggested an excellent forage program to supply the forage needs for 100 ewes and 150 lambs for a year on just 12.14 ha. To obtain such a high carrying capacity and fat lambs, it is necessary to seed one-third of the area to cereal crops and a warm season grass for temporary pastures. However, if lambs are early weaned and it is assumed that one ewe can graze in the place of three lambs, ewe numbers can increase by 50%. Thus, under feed and lamb prices usually existing in the Midwest, income per ha could be increased by $30 to $50. Further, the added equipment cost and risk of soil losses that may occur in the establishment of temporary pasture may be reduced by replacing temporary pastures with a wintering pasture (fescue) and/or a legume-grass mixture which should be adequate for maintaining dry ewes.

Finally, the interest in early weaning as a management practice to control parasites, to reduce predator losses and to expedite accelerated lambing prompted studies on young lamb diets. Scientists thought that this very young, rapidly growing lamb needed more protein than that usually recommended for typical feeder lambs. Copenhaver and Carter (1968) stated that 15% protein was adequate. Hinds *et al.* (1964) found that the rate of gain improved when lambs were fed a diet containing 17% crude protein. Work at the Dixon Springs Center has indicated that forage levels in complete, self-fed diets should be between 10 to 25% for most rapid gains. When forage is limited to 10% of the diet, quality of forage seems to have little effect on rate of gains (Table 6). If cereal grains are costly in relation to lamb prices, lambs will gain relatively well on diets of 50 to 60% forage, but high-quality forages will be necessary. Studies on protein levels of early weaned lambs (6 to 8 weeks) indicate the level necessary for maximum performance is approximately 17% of the diet.

TABLE 6. Feed and gain data for lambs fed various forages at 10% of their diet

Forage Component	ADG (kg)	F/G	Average Daily Intake (kg)
Alfalfa	.22	5.63	1.25
Legume/grass	.24	5.47	1.28
Fescue pasture clippings*	.27	4.71	1.27
Soybean residue*	.23	5.87	1.33
Corn stalk*	.20	6.00	1.20
Sawdust	.24	5.34	1.24

*Stacked over winter.

In discussing management programs using early weaning and confinement, it was not intended that this should detract from the value of sheep as a grazing animal. They are very efficient in converting forages to a high-quality carcass that can be very valuable in providing the protein badly needed in diets of many in the world. Lambs are capable of producing carcasses of market weight and grade that will command top prices on forages alone. In the United States, sheep numbers should be increased in relation to beef cattle numbers for most efficient forage utilization (Van Keuren *et al.*, 1967).

The overall purpose of this paper has been to outline several programs which may apply under

various environmental and economic conditions. The choice of a system in the total sheep management program is of less importance than a clear appreciation of the modifications that can be made.

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135.
Present Use and Development Potential of Hill Land in Ireland

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EXTENT

The National Soil Survey in its classification of the total land area of Ireland shows 1.4 million ha (21%) as mountain and hill soils and 0.5 million ha (7%) as organic soils (Gardiner and Lee, 1969). This gives a total of 1.9 million ha of rough grazing in Ireland. Unfavorable climatic and geographic features and a decreasing population seriously affect the agricultural utilization of this area, and farming systems are relatively undeveloped. Hill land in Ireland occurs mainly in coastal regions and between 150 and 300 m altitude.

CLIMATE

Ireland has a wet maritime climate, and mild, damp weather occurs in any month of the year. Hill regions have a mean annual rainfall of 1500 to 2500 mm. Snowfalls or severe frosts are usually of limited duration and are a serious problem in exceptional years only.

HILL LAND USE

There is a concentration of population in farming, and this in many cases is at subsistence level. Hill farms account for about 12% of all farms in the country and they sustain 0.4 million livestock units or 8% of the national livestock production (Walsh and Lee, 1972). Store sheep and cattle are the long-established and traditional industries with the hills acting as a source of store animals for lowland farms where the production process is completed. Cattle are reared on practically all farms and sheep on approximately 50% of farms. Farm sizes and consequently flock or herd sizes are small, and further problems arise from fragmentation of holdings and communal grazings.

THE SHEEP ENTERPRISE

Distribution

The hill sheep population is calculated as 0.8 million breeding ewes. State subsidization has led to substantial increases in recent years. The hill sheep distribution pattern, calculated from the 1974 Mountain Lamb Subsidy returns, is shown in Fig. 1. Stocking densities vary greatly and are influenced by several factors. In many areas, under existing

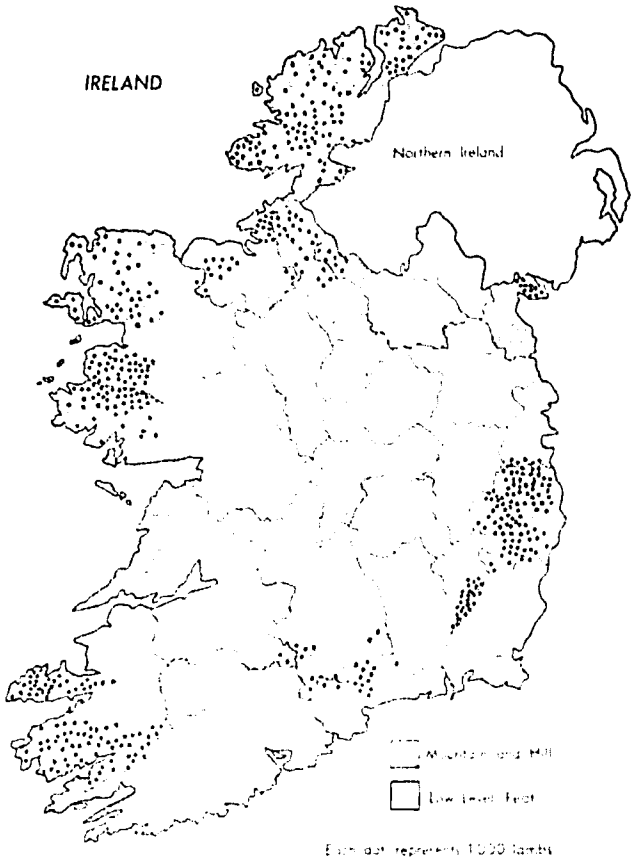

Figure 1. Hill sheep distribution in Ireland, 1974.

systems of management, stocking is limited to what can be carried during the winter months. This imposes constraints on output, particularly on farms with a limited area of land suitable for fodder conservation. Sheep production is also affected by the traditional system of giving all conserved feed to cattle.

In the west of Ireland, sheep are reared almost exclusively on the hill under an extensive management system. It is, therefore, possible to examine some of the geological, edaphic and botanical factors affecting their distribution in counties Galway and Mayo (Fig. 1 and Table 1).

The highest stocking density of 0.6 ha/adult sheep is achieved on the dry central unit extending to both sides of the Galway-Mayo border. This is composed mainly of Ordivician and Silurian sandstone, schist and gneiss. The soils are brown *podzolics* and peaty podzols, and these support a vegetation comprised mainly of *Agrostis tenuis, Nardus stricta, Anthoxanthum odoratum, Sieglingia decumbens* and *Festuca vivipara* (O'Sullivan, 1968). Further south in county Galway a very low stocking rate of 2.5 ha/sheep is found on deep wet peat overlying granite. Here the vegetation is composed mainly of

TABLE 1. Sheep stocking density on different soil and vegetation types

Geology	Soils	Vegetation	Stocking Rate (ha/ Sheep)
Sandstone	Brown podzolics Peaty podzols	*Agrostis tenuis* *Nardus stricta*	0.6
Granite	Deep peat	*Molinia caerulea* *Eriophorum angustifolium*	2.5
Quartzite	Shallow peat Skeletal peat	*Calluna vulgaris* *Molinia caerulea*	1.3

Molinia caerulea, Eriophorum angustifolium, Trichophorum caespitosum, Schoenus nigricans and *Narthecium ossifragum*. Deep peat in north Mayo also supports relatively low sheep numbers. In parts of Mayo and Galway, metamorphic quartzite forms rough mountain peaks with shallow and skeletal peat soils and peaty gleys. The dominant vegetation is *Calluna vulgaris, Molinia caerulea* and *Nardus stricta*. An intermediate stocking density of 1.3 ha/sheep is found on these hills.

Nutrition and Management

Breeding ewes graze on the hills for most of the year with limited access to improved fields near the farmhouse. Weaned lamb numbers vary with winter climatic conditions and usually average 70–75%. Store lambs of approximately 23 kg liveweight are produced. Inputs into sheep are low with very little supplementary feeding practiced.

Peart (1967) and his colleagues at the Hill Farming Research Organization in Scotland have shown that hill sheep are performing far below their production potential. To realize this potential, improved levels of energy intake are needed in all seasons of the year; a decrease at any one time can have serious repercussions on productivity at other times (Russel, 1971). The full benefit of supplementary feeding during late pregnancy would be obtained only in a situation where energy intake during lactation was adequate to support high milk yields and lamb growth rates.

At the Sheep and Mountain Land Research Station at Maam, supplementary feeding of hill ewes during pregnancy gave the best economic return when given to the section of the flock in poorest condition. This helped to maintain body condition at a minimum level above which the flock could survive and produce viable lambs. These lambs would then respond to further supplementary feeding or improved pasture if such were available. Table 2 shows the cumulative effects of extra energy when fed before and after lambing. Scottish Blackface ewes

TABLE 2. Effects of supplementary feed on lamb performance

Lamb at:	Control (no extra feed)	Supplementary Feeding: Late Pregnancy	Supplementary Feeding: Post-partum	Supplementary Feeding: Late Pregnancy and Post-partum
		kg		
Birth	3.42	3.60	3.42	3.61
Weaning	23.46	24.83	28.21	29.67

were given 20 kg of a barley/beet pulp mixture (a) before lambing, (b) after lambing, and (c) before and after lambing. Feeding during pregnancy had only a very marginal effect on lamb weaning weight in a situation where postpartum nutrition was obviously inadequate. With hill sheep farming carried out largely under a range system of management, mainly single lambs are produced. Such a system scarcely justifies the costs of concentrate feed inputs. If they are in good condition at mating, ewes bearing single lambs can withstand a fair degree of undernourishment by utilizing body fat reserves, thus producing a viable lamb. This lamb will perform well to weaning if ewe milk yields and pasture quality are adequate. With pasture improvement, ewe body weights also increase, giving an improved lambing percentage and a higher energy requirement during pregnancy the following year. The first point in the annual cycle for improving the standard of nutrition would, therefore, appear to center around summer nutrition for the lactating ewe and her lamb. At this point, also, returns on the increased investment would be immediately evident.

THE CATTLE ENTERPRISE

Statistics on hill cattle are difficult to obtain. Some good quality land within hill regions is devoted exclusively to cattle. Also, on hill farms, one sometimes finds sheep confined to the rough grazing land with the better land and all conserved feed available to cattle only. In some areas surveyed, sheep and cattle were farmed on a 50:50 livestock equivalent basis. This ratio, if applied to all hills, would give approximately 0.1 million cows. These are mainly beef animals, except in the southern part of the country where dairying is the main cattle enterprise.

MIXED STOCKING

Low herbage utilization on hill pastures has been described by Eadie and Black (1968). Sheep are selective feeders—both as to species they graze and in the part of the plant eaten. Less desirable species, such as *Molinia caerulea* and *Nardus stricta*, are to a great extent avoided by sheep, except in the very early stages of growth. But they are well utilized by cattle. Mixed stocking of plant communities dominated by these species resulted in improved utilization and consequently increased production (O'Toole and Kiely, 1972). Greater sheep grazing activity was observed on areas previously grazed by cattle, and mixed grazing systems gave higher animal production than either sheep or cattle alone. When single suckled cows were introduced to a hill traditionally grazed by sheep, liveweight gains of the calves averaged 0.7 kg per head per day. There was no decrease in sheep production.

However, there is a limit to what can be achieved with mixed stocking and increased utilization of hill species. Hill soils generally are low in fertility and stable plant communities have adapted themselves to these conditions of low nutrient balance. In some cases, the survival of the individual species is dependent on low utilization and a return of nutrients from the decaying herbage. This is particularly true of wetland species at the lower end of the fertility scale. Table 3 shows the botanical change over a five-year period brought about by increased grazing pressure on a bogland community dominated by *Molinia caerulea*. Utilization, measured as ingested herbage, was increased from 17% to more than 50%. The rate of deterioration is apparent from the increase in bare ground and *Sphagnum* species. These effects, due to acceleration of the nutrient extraction process, could be counteracted by small fertilizer inputs.

FARMING SYSTEMS

It would be inadvisable to generalize on hill land farming systems because of the variation in soils, vegetation and land use limitations. The system best

TABLE 3. Percent contribution by plant species in a bogland community subjected to different grazing pressures over a five-year period

Species	Grazing Pressure: Grazed by Sheep, 17% Utilization	Grazing Pressure: Grazed by Cattle, 52% Utilization
Molinia caerulea	31	25
Eriophorum augustifolium	29	21
Tricophorum caespitosum	17	13
Schoenus nigricans	8	7
Marthecium ossifragum	6	6
Sphagnum species	4	13
Bare ground	5	15

suited to each farm is an individual matter, although some general principles do apply.

With traditional hill farming in Ireland based on a range system of management, animal density over the years adjusted itself to climatic conditions and feed supply. Inputs were low and returns were also relatively low. To some extent this position is likely to continue. Inputs will remain relatively low and these will have to be injected into the system at the point of greatest return. This should be in the form of increased fertilizer usage for improved summer grazing and conserved feed for the winter.

The potential for increased sheep production on Irish hills appears large. This should be aimed at improving output per ewe rather than increasing ewe numbers. Cattle also present great possibilities for pasture control, better utilization and increased production. Plant species, such as *Molinia* and *Nardus*, poorly utilized by sheep, predominate on Irish hill soil types. It would be unrealistic, however, to suggest mixed stocking for hill land in general. Cattle are restricted by slope and increasing altitude and would have to be grazed mainly on the foothills.

LAND RECLAMATION

It has already been pointed out that the major limitations in hill farming are poor quality of summer grazing and scarcity of conserved feed for winter. Newbould (1974) has shown the amount of thought and effort put into hill pasture improvement in the past. The integration of improved pasture with the open hill is of utmost importance, and the farming system and level of output achieved is largely determined by the quality and quantity of this pasture.

Many of the drier hill slopes in Ireland, supporting *Agrostis* and *Nardus*, are suitable for fertilizer application. Unfortunately, most of these are slopes of 20–30° which cannot be traveled by ground machinery. Aerial fertilizing is now a definite possibility following very substantial increases this year in the price of annual products from the hill. Parts of the foothills can be negotiated by specialized ground machinery, and improvement of these should be the first consideration. For fodder conservation, the flatter, wetter areas may have to be reclaimed. Costs are then higher and can only be justified if the developed area is used in such a way as to have maximum impact on animal performance on the hill.

Rough grazing with the greatest potential is *Calluna* dominant land of 5–12° slope at low elevation. This is being very successfully plowed and reseeded. The soils are usually peaty gleyed iron pan podzols and peaty podzolized gleys. Plows capable of plowing to a depth of 60 cm or more are used to break the impervious layers and mix them with the shallow peat layer at the surface. Greatly improved structure and permeability results from this plowing and mixing.

SOCIAL AND ECONOMIC FACTORS

The human population of any area is its most important resource, and the rate of social and economic development is greatly influenced by the demographic situation. In mountain regions in Ireland, the demographic characteristics of the present population constitute a definite obstacle to development. The vitality of a community is influenced by the age composition of its population. Poor soil resources and the concentration of the majority of the population in farming with little alternative employment have provided the ideal emigration situation. The younger, more active and better educated sections of the community tend to migrate, leaving a residual population with a very high proportion dependent on working members and on the State. There are few employment opportunities for girls in agriculture or otherwise. This adds momentum to the female emigration rate and decreases marriage prospects for young farmers staying at home. In the west of Ireland, Scully (1971) found that 59% of hill farmers were over 50 years and only 17% less than 40 years of age.

The major problems affecting hill land use in Ireland are, therefore, social and economic rather than lack of technical data. With a preponderance of older people in agriculture, it is unlikely that new ideas will be readily accepted or implemented. On the other hand, the small size of enterprise fails to generate sufficient capital to enable the younger and more energetic farmer to develop and expand. Present incomes are far too low in the majority of cases to give any hope of elevation to the level envisaged in the European Economic Community Directive 159. Also, assuming that retirement schemes could be implemented and that land restructuring obstacles could be overcome, there still would be insufficient land to give farmers under 55 years of age the desired level of income. An increased flow of people out of agriculture is, therefore, inevitable. This necessitates the relatively free availability of off-farm employment. Solutions to many of the problems must be sought outside agriculture, such as in tourism. This is a developing industry in an unspoiled area which has many cultural, scenic and recreational attractions. First class fishing, game, hill walking, mountain climbing, pony trekking, beaches and cliffs are all available.

On the brighter side, the organizational structures for economic and social development of mountain regions are gradually building up. Several hill farming cooperatives are now in operation. These are engaged in land reclamation, marketing, social and cultural activities. In my opinion, this involvement of people in solving their own problems is the only base on which development structures can be built. In the long term, it should have the desired effects in mountain region development.

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DISCUSSION

J. Eadie (Scotland). The question, with respect to those situations in which you get no response to supplementary feeding, is this an extensive hill situation in which there is a good deal of cotton grass? This may, in fact, provide the reason why, in what is in other respects a very extensive situation, you get no response with supplementation because I wouldn't expect in our circumstances you would get much of a response with supplementation if significant areas of that particular plant were present. The comment is that we weigh, as you know, very great stress not only on the need for improved land, but also on the management strategy. If I had time, I would have gone on to consider this management strategy in more detail.

Implicit in the argument, however, is that if you address this limited amount of land improvement to the problem by developing an appropriate management strategy, you will, in fact, maximize the response. And I think this relates to a comment that you made earlier in your paper.

O'Toole. The first part of your question, in relation to the type of situation you're in, is important if you're in a cotton grass situation; you do find feed there all the winter for the sheep. However, in that situation, as you very well know, you'll get a low stocking rate. Very much below one ewe per acre. So in our situation, it's to some extent on the green hill. What I found most interesting about this is that this requirement for feed in pregnancy on the single lamb system seems to be a ewe characteristic rather than a pasture feature. Where we did get response, it seemed to be in a small percentage of the sheep, which would suggest that a lot could be done in selecting sheep for this situation. The figure would go from 10 to 15% of the total flock and the better ewes in the flock. The problem also gets complicated, as you know, by sheep picking out better areas of the hill for themselves, and these will tend to take the winter better. All I can say on the last comment is that I agree with you in that management strategy is very much a part of this and you have such variations between hill farms that you just cannot generalize at all about what you want to do on any hill farm in our situation.

136.
Responses in Output Achieved from Improved Systems of Hill Sheep Production

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PART I.
IN THE EASTERN CHEVIOTS

Hill sheep farming in the United Kingdom takes place in a wide range of hill environments that differ in climate, soils and vegetation. The output per unit area from hill farms is low due to low stocking rate and poor to moderate levels of individual sheep performance. Pasture production also is poor, and this is accompanied by low levels of pasture utilization that occur as a consequence of the traditional year round, free grazing, set stocked system of management. Because pasture growth is greatly under-utilized, there is an accumulation of dead herbage, which leads to a poor cyclical pattern of nutrition (Eadie, 1971). Poor individual animal performance is generally a consequence of poor nutrition. Information on the relationships between nutrition and hill sheep performance has been summarized and discussed by Russel (1971).

The synthesis of an improved system of hill sheep production has been described by Eadie (1971) and Eadie and Maxwell (1975).

The basis of this synthesis is the improvement, by one or a variety of means, of a proportion of the natural indigenous vegetation. The improved pasture, which provides higher levels of nutrition than the indigenous hill pastures, is used at times when its impact will be greatest on animal performance. It is grazed during lactation to improve milk production, early lamb growth rates and early ewe body weight recovery. It is used again during the pre-mating and mating period to further enhance and maintain ewe body weight and condition, and thereby increase conception rates. Improved nutrition at other times of the year leads to a need for improved nutrition during late pregnancy, and this is met by the use of purchased cereal/protein supplements.

The provision of improved pasture not only gives a better quality feed but a greater quantity of feed. This leads directly to the possibility of increasing stock numbers and indirectly to the possibility of an increase in the utilization of the indigenous hill pastures at appropriate times in the production cycle.

The synthesis has been tested as a whole production system. Scale of operation and its biological and husbandry implications, diversity of vegetation and the fact that no two hill grazings are alike are just some of the factors which preclude the use of the classical "treatment and control" experiment.

The method adopted is essentially one in which inputs in the form of fencing for grazing control, pasture improvement and feed are applied through time, and the response is measured in terms of individual animal performance and total output. Since total output is a function of output per animal and stocking rate, stock numbers are progressively increased to the point at which output per ewe declines and the change in total output is measured (Mott, 1961). Figure 1 demonstrates theoretically and diagrammatically the approach adopted.

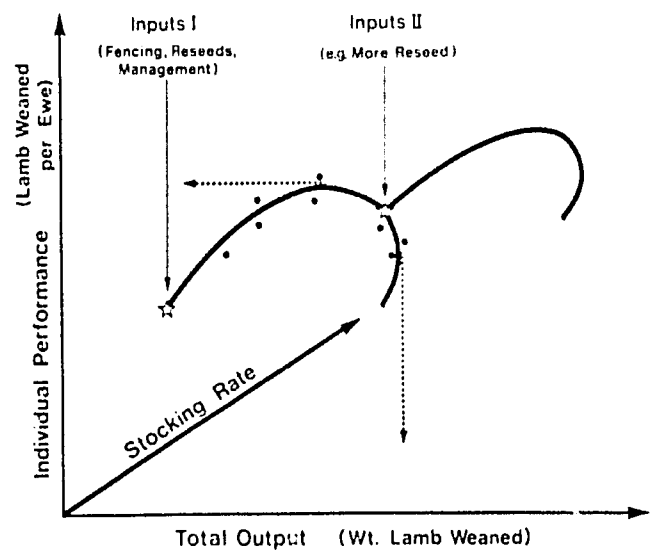

Figure 1. Theoretical responses relating individual output, stock output, flock output and stock numbers.

The limitations of the approach might be regarded as serious if the changes in output were to be in the region of 10–20%; much larger changes in output may, however, be assumed to result from system and input changes.

The study is at the Organization's research station at Sourhope situated in the eastern Cheviots in the

south of Scotland; the hill grazings are typical of the Southern Uplands. The soils on the lower slopes tend to be acid brown earths carrying an *Agrostis-festuca* vegetation. The higher slopes and plateaux are *Nardus* and *Molinia* dominant on podsolic and peaty podsolic soils. The *Agrostis-festuca* pastures, which are often bracken covered, amount to some 25–40% of the grazings. The average annual rainfall is 900 mm. Substantial snowfalls can occur between mid-November and late April, but there is great year-to-year variation in the frequency of snow storms and in the extent to which grazings are covered by snow.

The application of the synthesis at Sourhope centered initially on the use of improved indigenous hill grazings. Eadie and Black (1968) demonstrated that the more intensive grazing of *Agrostis-festuca* pastures in a system of controlled grazing would not only improve their utilization but also their quality by reducing the amount of dead, poor quality herbage normally carried on such pastures in the traditional free grazing system.

The area chosen for the study extends to 283 ha, ranging in altitude from 250–450 m. Approximately 40% of the area carries an *Agrostis-festuca* or bracken covered *Agrostis-festuca* vegetation. The unit carried 398 Cheviot sheep at the start of the study in November, 1968. Previously, in addition to sheep, beef cows had grazed the hill, but these had varied in number and seasonal incidence of grazing. It was decided to graze 24 spring calving beef cows on a permanent basis from May to the end of December.

Initially two areas of *Agrostis-festuca* pasture, each of 20 ha, were enclosed and heavily grazed by cattle and dry sheep during the summer of 1968. Much of the dead herbage was removed, and the regrowths were ready for use by the ewes during the pre-mating and mating periods. Three further areas of 20 ha were enclosed and treated in a similar manner in 1969, 1970 and 1972.

To insure an effective removal of the dead herbage, it is important that the size of the area enclosed is such that the number of animals available for grazing per unit area is high enough for short periods of time (10–12 ewes per ha).

The strategy was to integrate the *Agrostis-festuca* paddocks with the open hill in the manner already described: to supplement winter feed during periods of storm with hay or sugar beet pulp and during the six-week period before lambing with a cereal/protein based concentrate and to increase ewe numbers to the point at which individual ewe performance began to decline.

The first phase of the study took place between 1968 and 1974. During this period, ewe numbers were increased from 398 to 600. Figure 2 shows how output of lamb per ewe and total output of lamb changed together with the increase in stock

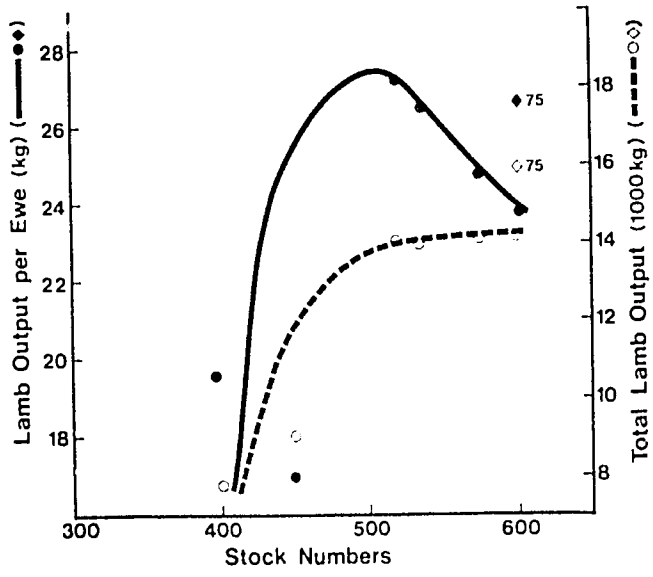

Figure 2. Sourhope—Hairney Law Auchope. Output of lamb per ewe (kg), total output of lamb (kg) and stock numbers.

numbers. The total output of lamb increased by over 80% within three years; this was obtained from both increased individual ewe output and from a stocking rate increase of 30%.

Output per ewe increased from 19.8 kg of weaned lamb in 1969 (398 ewes) to 28.0 kg in 1971 (514 ewes) and 27.0 kg in 1972 (529 ewes). Thereafter, a fall in output per ewe to 24.9 kg in 1973 (573 ewes) and 24.2 kg in 1974 (597 ewes) took place.

The decline in ewe performance in 1975 is accounted for partly by a fall in weaning percentage to 100 from 105 in the preceding year. In addition, mean lamb weaning weight declined from 26.6 kg in 1971 to 25.4 kg in 1972 and to 24.9 kg in 1973.

Weaning percentage fell markedly to 92 in 1974. This followed a substantial fall in mean pre-mating body weight from 59.3 kg in 1972 to 53.7 kg in 1973 (Fig. 3). By 1973, the increase in ewe numbers had reached a point at which summer nutrition had become inadequate to promote the levels of ewe body-weight recovery experienced in previous years.

An essential element in these studies is to increase stock numbers to the point at which individual animal performance is significantly depressed. This had been achieved by 1974, and a further set of inputs was made during that year. Two of the *Agrostis-festuca* areas were limed and fertilized with ground mineral phosphate, and bracken spraying was carried out on one of them. Two reseeded areas totaling 18 ha, which had been created many years previously, were also introduced for the main purpose of grazing ewes rearing twin lambs.

The effect of this second set of inputs is seen clearly in Figs. 2 and 3. Pre-mating body weight increased from 53.7 kg to 55.3 kg, and both the

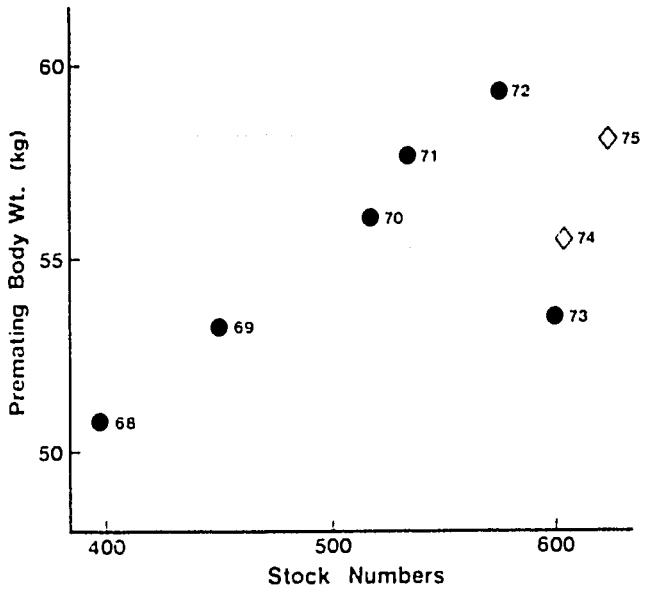

Figure 3. Sourhope—Hairney Law/Auchope. Premating body weights and stock numbers.

output of lamb per ewe and total lamb output have increased. The study continues.

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PART II.
ON BLANKET PEAT IN THE WEST OF SCOTLAND

J. Eadie, T. J. Maxwell, and D. C. Currie

The second study is located at the Organization's research station in the west of Scotland at Lephinmore, on land rising from sea level to around 500 m on the eastern shore of Loch Fyne in the Cowal district of Argyll. The average rainfall is 2 000 mm. Most of the hill is covered by blanket peat and the vegetation is dominated by heather (*Calluna vulgaris*), draw moss (*Eriophorum vaginatum*), deer grass (*Trichophorum caespitosum*), with some *Molinia*. The blanket peat vegetation is broken by flush areas carrying a *Juncus* dominated grassy pasture. Some of the steeper slopes are peaty podsolic, but the afforestation which took place on this station in the early 1950's effectively removed most of these better areas from sheep grazing.

The Midhill unit on which the study is based extends to 444 ha and rises from near sea level to 500 m. It includes a substantial amount of "downfall" left at the time of afforestation, as access to the higher grazings.

A previous study on Midhill began in 1956; land improvement and enclosure began in 1957. Prior to this, output was very low and ewe performance was poor; weaning percentages were around 50-60 and stock numbers around 230 ewes.

By 1968, knowledge had improved to the point at which the synthesis briefly described in this paper provided the basis for a rather different emphasis to the objective, in terms of grazing management, outlined by Nicholson and his colleagues (1968). The significance of utilizing improved pastures during lactation, and again after a mid-season rest, in the period prior to and including mating, suggested a substantial change from previous management. It had been the practice during 1957-68 to return lactating ewes to the abundant, but poorer quality, indigenous hill pastures during late June, July and August when these pastures were growing rapidly. The improved pastures tended to be undergrazed during this period.

In 1968 the land available on Midhill (444 ha) was as follows:

(a). Two enclosures totaling 69 ha, 20% of their area being improved as 1-2-ha patches distributed throughout;

(b). 14 ha of enclosed, permanent but improved grass fields;

(c). an improved area of 7 ha used also as a lambing paddock.

The remainder was unimproved indigenous hill vegetation—approximately 350 ha.

In an attempt to arrest the decline in performance during the first study (shown in Fig. 1) (230-372 ewes) and in response to the relationships between stock numbers and pre-mating ewe body weight (Fig. 2) and weaning percentage (Fig. 3), flock size had been reduced from 384 to 330 ewes in 1968.

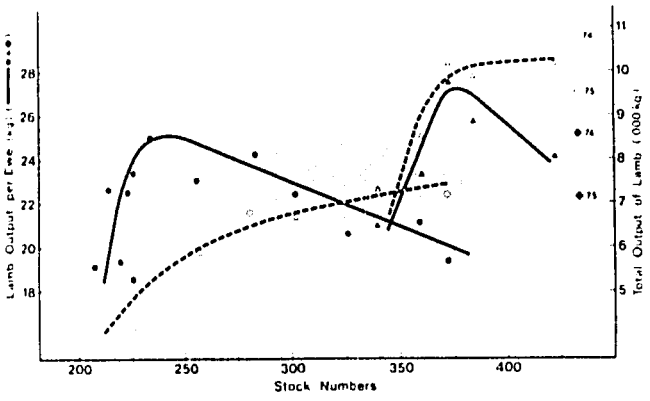

Figure 1. Lephinmore—Midhill. Output of lamb per ewe (kg), total output of lamb (kg) and stock numbers.

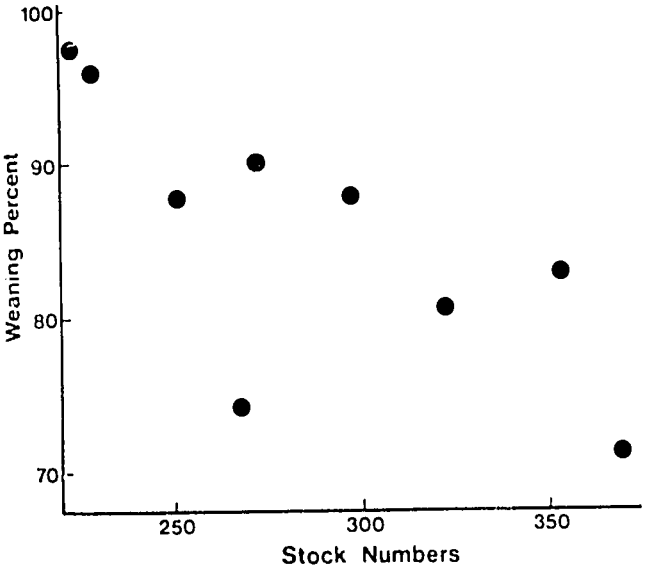

Figure 2. Lephinmore—Midhill 1962-1968. Premating body weight and stock numbers.

During 1969, the change in management strategy was effected. The effect of this change of ewe pre-mating body weight became quickly apparent; for example, pre-mating ewe body weight increased from 44.0 kg in November, 1968 to 49.3 kg in November, 1969. Consequently, the process of increasing ewe numbers was begun again. This was done so that the effect of the changed strategy could be effectively tested by means of a comparison of

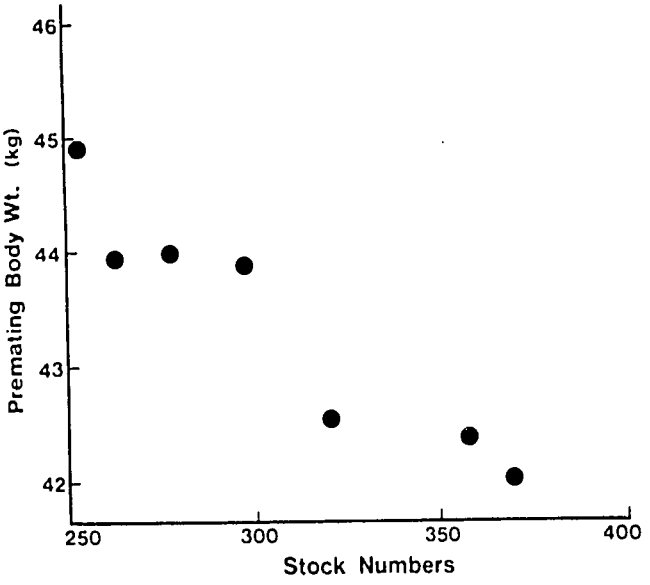

Figure 3. Lephinmore—Midhill 1962-1968. Weaning percentages and stock numbers.

the relationships between ewe numbers and individual ewe performance. The range of ewe numbers in the "new" situation had, therefore, to overlap and go beyond the maximum stocking rate achieved in the "old" situation.

From 1969 to 1972, ewe numbers were progressively increased from 339 to 384. The maximum stocking rate previously attained in 1968 (372) was reached in 1971.

Total output of weaned lamb increased from 7 200 kg in 1969 to 10 268 kg in 1971, and it remained at around this level until 1974.

Weaning percentage increased from 85 in 1969 to over 103 in 1971, at which level it remained until 1972. Output of weaned lamb per ewe increased from 22.0 kg in 1969 to 27.5 kg in 1971 after which it declined in 1972, reflecting a reduction in lamb weaning weights.

The relationship between stock numbers and individual performance for each of the phases (Fig. 1) shows that the changes in management strategy initiated in 1969 had a considerable beneficial effect on both total output and individual ewe performance.

Data in 1972, however, suggested that ewe body weight recovery between marking and weaning had been appreciably less, and that during the mating period of that production year (1971-72) ewe body weight loss had been significantly greater than in previous years. Pre-mating body weight had declined.

The relationships between ewe pre-mating body weight and weaning percentage and output per ewe which have been obtained from data from this flock from 1963-1974 are shown in Fig. 4 and

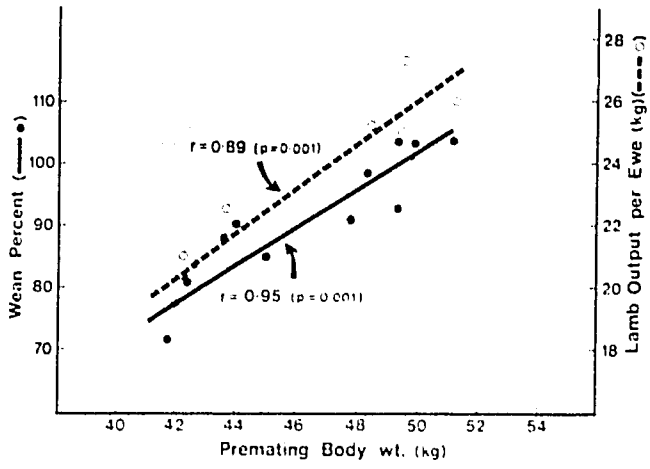

Figure 4. Lephinmore—Midhill. Premating body weight, weaning percentages and lamb output per ewe.

indicate that performance in the Scottish Blackface ewe is very responsive to changes in pre-mating body weight. The next phase of the study was initiated and four ha of previously improved pasture was utilized for the first time in the autumn of 1972. During 1973, another eight ha of indigenous pasture was improved within the enclosures which already contained the mosaic of improved reseeded patches.

In anticipation of the contribution of these further improvements, the stocking rate was increased from 384 to 422 ewes in the autumn of 1972, to 433 in the autumn of 1973, and to 434 in the autumn of 1974. Although total output reached a level of 10 870 kg in 1974, and output per ewe had shown some improvement compared to 1973, there was a marked reduction in both total output and output per ewe in 1975. Pre-mating body weight continued to decline slowly during this period (1972–75).

A delayed response to the inclusion of an additional 12 ha of improved pasture would not have been entirely unexpected, as improved pastures are slow to come to full production in this environment. But by 1975, there was no evidence that any reversal in the decline in body weight recovery during the summer and autumn had occurred.

A more detailed examination of this decline shows that from marking to weaning, when the ewes are on the improved pastures, ewe body weight gains in 1974 and 1975 were half of those achieved in the first two years of the study (1969 and 1970). The ewes are again on the improved pastures from the end of September until the end of the mating period (towards the end of December), but the tendency during this period is for a slight improvement to have taken place over the years.

Ewes were entirely dependent on indigenous pasture from the end of December until mid March until 1972. Since 1973, in response to storm conditions and to lower absolute body weights, pre-lambing feeding has commenced somewhat earlier, and body weight losses have not increased during this period.

Thus the evidence strongly suggests that the decline in performance of the flock since 1971 is associated with inadequate levels of nutrition during the summer while ewes are grazing the improved pastures. There also is a suggestion that stocking rates are approaching a level at which grazing pressure on the indigenous hill area during the period from weaning to mid September is beginning to depress rates of ewe body weight gain. The importance of establishing clearly the stocking rate at which pressure on the indigenous pasture leads to a significant decline in the rate of ewe body weight recovery is discussed in more detail elsewhere (Eadie, 1976). Briefly, within the current management strategy, there is a point (which will vary from one kind of hill pasture to another) beyond which further increases in stocking rate, brought about by further increments of improved pasture, will lead to a deterioration in rate of gain or exacerbate a loss in weight during those periods when sheep are on indigenous pasture. From that point on, management strategy must be changed to meet the situation.

At present, uncertainty clouds the extent to which such a point has been reached in the current study, and in an attempt to clarify the matter the stocking rate was further increased to 460 ewes in the autumn of 1975.

In conclusion, the responses in output in this study and that outlined in Part I demonstrate that the synthesis outlined by Eadie (1971) provides a means of increasing substantially the output of lamb from many of the hill and mountain areas of the United Kingdom. The economic aspects of increasing production from hill sheep farms are discussed in a companion paper (Maxwell, Eadie and Sibbald, 1976).

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137.
Grazing and Pasture Management Trial of Coos County, Oregon, USA

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The 81 000 ha of hill land in southwestern Oregon has the capacity to produce more than 5 000 kg of forage per ha annually when soil nutrient deficiencies are corrected. The application of phosphorus, sulfur and molybdenum fertilizer has made it possible to reach this level of production from subclover-grass hill pastures within a few years.

The climate of the area is mild, allowing 12 months grazing with a minimum amount of livestock supplemental feeding. Unimproved hill pastures support less than 1 sheep per ha. Improved pastures producing 5 000 kg per ha air dry forage should be capable of supporting 7 to 10 ewes per ha if grazing management systems to utilize this forage are developed and demonstrated.

About two-thirds of the forage production occurs from April 1 to July 1 in this area of Oregon. Livestockmen, after observing the results of phosphorus, sulfur and molybdenum fertilizer applications to subclover hill pastures, were unsure how to manage grazing of improved pastures to utilize the increased forage production.

The need for a grazing management trial and demonstration in Coos County, Oregon, was discussed with Dr. M. D. Dawson, professor of soils, Oregon State University; Dr. McGuire, farm crops professor, Oregon State University; and Dr. E. Gardner, extension soils specialist, Oregon State University. After developing plans for the trial, local ranchers R. C. and J. J. Geaney volunteered to provide land and livestock for the trial.

Four ha of undeveloped red hill soil (Dement silt loam) on the Geaney ranch were selected for the project. Located at 124° 10′ W and 43° 15′ N the area averages 150 cm of rainfall annually. Average annual temperature for the area is 11.8 C. Soil chemical analyses are listed in Table 1. Seedbed preparation on one-half of the area was made with a crawler tractor and a disc plow working the soil 30 to 45 cm deep. The other half of the area was prepared by disc harrowing to a depth of 7 to 16 cm. The area has a 20% slope to the south. The disc harrowed area was seeded October 16, 1970 and, due to equipment breakdown, the disced plowed area was seeded October 29, 1970.

Both areas were seeded to subclover *Trifolium subterranium* and perennial ryegrass *Lolium perenne*. Following seeding, the area was subdivided into four one-ha pastures. Phosphorus and sulfur were applied to the pastures at two rates—an average and a high rate. Each pasture received 420 g Mo/ha at seeding time and again in the fall of 1975. Table 2 lists fertilizer treatments and stocking rates.

The grazing intensity was applied at two rates—low (3 to 4 ewes per ha) and high (6 ewes per ha). The grazing rates were arranged so each grazing

TABLE 1. Summary of chemical analysis of soil samples from pastures

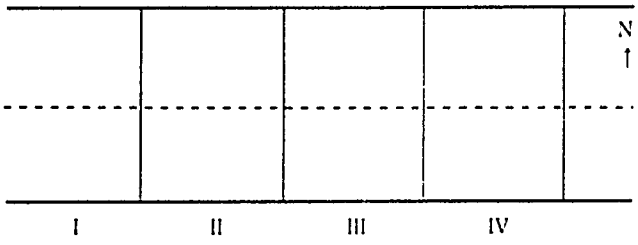
Pasture	Date	pH	P[a] ppm	K[b] Meq/100g	Ca[b] Meq/100g	Mg[c] Meq/100g
Total area	Sept. 70	5.4	13	1.24	4.1	2.0
1	March 71	5.6	3	.95	4.4	2.2
3	March 71	5.7	3	.90	4.4	2.4
1	March 73	5.4	7	1.02	3.8	1.6
2	March 73	5.4	7	1.31	7.0	3.0
3	March 73	5.3	9	1.18	6.4	2.7
4	March 73	5.3	10	1.23	7.3	2.7
1	June 74	5.1	8	.83	2.9	1.1
2	June 74	5.2	7	1.15	6.8	2.9
3	June 74	5.0	7	.78	5.8	2.6
4	June 74	5.0	9	1.07	3.8	1.8

[a]Dilute Acid-Fluoride Method (Bray).
[b]Ammonium Acetate Method.
[c]Curcumin Method.

TABLE 2. Grazing trial map fertilizer treatments and stocking rates

Pasture	Fertilizer Rate per ha			Stocking Rate, Ewes per ha
	P	S	Mo	
1	40kg	50kg	420g	3
2	20kg	25kg	420g	4
3	40kg	50kg	420g	6
4	20kg	25kg	420g	6

GRAZING TRIAL MAP



rate was applied to both levels of fertilizer application.

The grazing was delayed after seeding until May, 1971, to allow pasture establishment. The pastures were stocked with grade Romney ewes and grazed year around. The ewes received a small amount of supplemental feed in January and February.

Lambs were weighed individually from each pasture in 1974 and 1975. Lamb weights for 1971 were based on an average weight for all lambs from the plots. Due to loss of lambs late in the season to predators, it was necessary to average weights of lambs from the pasture based upon the weights of surviving lambs.

LIVESTOCK PERFORMANCE

Animal performance was not measured the first year due to loss of all the lambs to predators during May and June, 1971. All 18 lambs and several of the ewes were killed by predators. In 1972, 18 lambs, with an average weight of 31 kg, were sold from the four pastures on June 28, 1972. The gross return per ha was $59.08 at the three ewe per ha grazing rate and $118.16 at the 6 ewe per ha grazing rate. In 1972–73, predator losses again were severe and no lamb weights were obtained.

Grazing was resumed for the 1973–74 year and in early July, 1974, lambs were weighed individually from each of the pastures (Table 3). Predator losses made it necessary to use average weights for the lambs for the four pastures. At the lower grazing rates, 124.5 kg per ha of lamb was produced with 152.4 to 240.9 kg per ha of lamb produced at the high grazing rate. Income per ha ranged from $107.84 to $209.49.

Production in 1975 ranged from a low of 136.2 kg per ha to a high of 207 kg per ha (Table 4). Lambs from the higher stocking rate pastures tend to weigh less, but total production per ha is much greater. The ewes in the trial maintained better condition and produced heavier lambs than ewes on adjacent grazing areas outside of the trial pastures.

FORAGE GROWTH

The heavier stocking rate has the advantage of controlling weeds which invade pastures where the forage is not completely utilized. Complete control of bracken fern, *Pterdium aquilinum var. pubescens*, and wild blackberry, *Rubus macropetalus*, was achieved in pastures 3 and 4. The forage was completely utilized and all areas of pasture were grazed, preventing the invasion of weed species.

In pasture 1 and 2, some forage was unused and wild blackberries and bracken fern competed for growing space. Sheep grazed areas heavily between clumps of weeds but left forage growing in conjunction with bracken fern and wild blackberry untouched. Selective grazing by the sheep in these two pastures allowed the weed species to gradually take over.

After five years observation of the trial, it is apparent four to six ewes per ha can be carried on hill pastures in southwestern Oregon if proper fencing and pasture fertility are maintained. At the stocking rates used, there was no apparent advantage of applying more than 20 kg of P and 25 kg of S per ha annually once the subclover and grass were established.

The heavier stocking rate has the advantage of controlling weeds which invaded lightly grazed pasture. Blackberries and bracken fern were well controlled in heavily grazed pastures.

Losses to predatory animals, mainly coyote, proved to be a serious problem in the trial just as it is a very serious problem to sheepmen in southwestern Oregon. The growth and development of the hill pasture resource and the sheep industry to utilize it are held back primarily by predatory animal losses.

DISCUSSION

W. Moser (Oregon, USA). You showed a shot on one farm where you had very good production of forage. Would you comment about the comparison of that particular area versus where you have these trials.

Cannon. Yes, I think what you're pointing out is that where we had this particular trial the potential production in that area is much lower than it is

TABLE 3. 1974 lamb weights and values

Pasture	No. of Ewes	No. of Lambs Raised	No. of Lambs Weighed	Av. Wt. (kg)	Total Adj. Wt. (kg)	Dollar Wool Value	Dollar Income Per ha
1	3	3	2	41.5	124.5	12	108
2	4	4	4	39.2	156.8	16	137
3	6	6	3	40.1	240.9	24	209
4	6	6	1	25.4	152.4	24	141

TABLE 4. 1975 lamb weights and value

Pasture	No. of Ewes	No. of Lambs Raised	No. of Lambs Weighed	Av. Wt. (kg)	Total Adj. Wt. (kg)	Dollar Wool Value	Dollar Income Per ha
1	3	3	1	45.4	136.2	9	110
2	4	4	2	38.6	154.4	12	125
3	6	6	3	34.1	204.6	18	166
4	6	6	6	34.5	207.0	18	167

in these other areas. So we would actually be able to reach much higher levels of stocking and production in some of the other areas of the county.

Moser. I don't really quite agree with Lynn. I think that the real problem that's involved is that at this point we have not grown subclover really successfully on the site that's involved. We have some other areas in the general vicinity where we have grown it quite successfully. I think that one of the problems is inoculation. I stressed this in my talk, and I think we need to go into additional work in inoculation to be sure that we get the potential production out of the plants we're putting there. The main thing, I think, is that obviously lambs produce as well at the high stocking rate as the low stocking rate, so we probably haven't anywhere near reached the top.

Cannon. I agree. I think the important thing to our ranchers was that even with this problem that you were referring to, we were able to get these levels of production.

L. Ainsworth (Ottawa, Canada). Is anything being done, particularly in the western states, with respect to covote control?

Cannon. Yes. There is a strong effort going on in Oregon and throughout the nation to bring about improved methods of controlling coyotes. Dr. Jim Oldfield from Oregon State is on the Western States Committee, which is working on predator research. One project that we're trying on this grazing trial will be putting a predator fence around it. We are going to put in a fence that has proved successful at Oregon State; it will be a 72" high fence; it will be tilted out at the top away from the fields so it will prevent jumping; it will have an apron at the bottom to keep them from digging under. In the areas where sheep production is most productive in our country, there is a lot of predator resistant fencing that is a great tool to help the government trappers that we have in the area trying to control predators. It's a similar type of construction.

Ainsworth. I might like to add in this context that the province of Alberta has been doing quite a bit of work over the last three or four years using the New Zealand electric fence, and this appears to be very efficient and effective in controlling coyotes. Have you tried this?

Cannon. There was an attempt to use it at Oregon State and they said it was unsuccessful.

Strategies for the Management and Development of Hill Land—Summary of Discussion Workshop

Editor's Note: *The workshop was held the evening of October 6, under the chairmanship of R. Koppelman, Provost for Research and Graduate Studies, West Virginia University.*

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What alternative strategies can be deduced from our observations and studies? There are three main possibilities:

Neglect

It is possible to neglect the hill lands and the struggle of their people to survive. Because they most likely will lose in the market place, people will leave, especially the young and the energetic. After a century of neglect, the "Massif Centrale" in France had become almost a stony desert.

Absorption Into National Life

A nation may wish to spend large sums to "assimilate" and "absorb" the mountain people into the main streams of national life. Very often this tendency is seen in cases where the ethnic background, the language, the culture, perhaps even the religion of the hill land people are different. These efforts then may become oppressive, dominating. Almost certainly they will be rejected by the proud and independent (in their thinking) mountain people.

Enabling Strategies

These strategies would involve efforts to assist the mountain people in self-determination, self-help and progress—recognizing and allowing or even promoting the special character of the people in their environment. Admittedly, this is a difficult task, but the symposium has been—even if submerged under technical, biological, and environmental problems—practically unanimous that this would be the appropriate strategy. This then leads to questions of:

FOLLOW-UP

Members of the discussion group and other participants made a number of valuable suggestions:

Research

Almost all the scientific contributions indicated that many avenues of research need further exploration before we can establish sound and valid advice for the users of the land. This also applies for the interesting but complicated issues of environment, including under-utilization and over-utilization (overgrazing, etc.) which leads to erosion of resources.

Communication

There is need for continuation of the channels of communication—international, interagency, and interdisciplinary—which were established at this symposium. We felt that we know too little; we certainly do not know enough of other peoples' problems and progress.

Comparative Analysis

Every participant learned so much from others, that a more systematic comparative analysis is needed.

The sub-arctic and cool temperate zones may suffer from insufficient sunshine, low temperatures, short growing season. On the other hand, in tropical and sub-tropical areas, drought, rapid decay of organic matter due to high temperatures, but ample sunshine are problems and a different "climate" prevails. In temperate zones, like many parts of the Appalachians, South Germany and the like, the microclimate has enormous influence on the potential land use. Whereas many problems of hill land are universal (small rural communities, relative isolation, costly transportation of means of production and of products) some features of the natural environment (slope and climate) make for great differentiation. Adaptation of ideas from other areas may lead to a variety of techniques for greatly improved economic and social conditions.

Population

A warning was given that all hill land is relatively overpopulated, even at low absolute densities. They all are net out-migrating areas, and often earn a large part of their income from emigrants. Thus, unless population policies are assiduously pursued in hill land (difficult because of isolation and traditions) relative overpopulation may worsen.

Land Ownership

Perhaps one of the most critical deterrents to positive strategies is land ownership. There may be absentee ownership over large areas, with tenants

too poor to be interested in investment. Alternatively, where the people cling to their land as their only hope, excessive subdivision may stand in the way of improvement.

Absentee-ownership also may be the result of out-migrants holding to their traditional property as a safeguard in case of failure in mass-society, or as a home to which to retire.

It should be kept in mind that all three adverse situations may exist side-by-side over a long period.

Integrated Approaches

Mr. Nepali from Nepal made a strong plea for an integrated approach, doing away in the field and in contact with the families with traditional functional divisions and subdivisions of services.

International Cooperation

For the U.S.A. new legislation favors the development of ongoing contractual arrangements between American institutes of higher learning in the area of food and agriculture and higher institutions in other parts of the world.

Taken together, in the view of this reviewer, the Symposium clearly showed the way to more concerted and coordinated research and action. Regret was expressed that the International Consultative group (with World Bank and FAO participation) has as yet no programs dealing with the specific issues of people and land in hill land.

Therefore, the immediate problem of strategy revolves around the question: What institutions and what categories of people will keep the ball rolling?

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