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ABSTRACTS

First International Rangeland Congress



Denver, Colorado
USA
August 14-18, 1978

SOCIETY FOR RANGE MANAGEMENT

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Plenary Session

RANGELAND RESOURCES AND WORLD FOOD NEEDS

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World population is projected to be about 6.3 billion by the end of this century with 80 percent living in developing countries. To meet the rising demand for food in these countries, their food production should be more than doubled. The demand for animal products will increase at least at the same rate. Rangeland provides at present the major part of feed consumed by ruminants in many developing countries of Latin America, Africa, the Near and Middle East. Low productivity and misuse are widespread. The high food demand of the future will increase the pressure on this land resource, particularly also their productive use. The development of ecologically and economically sound land use concepts, of long-term policies for livestock development and the establishment or strengthening of administrative, extension and research organizations are stressed as important elements at national level to introduce range improvement measures. To make the range part of a production system through various forms of stratification must be part of the livestock policy. The need for improved information on rangeland is highlighted together with the transfer of known technology from similar environments and the need for its careful adaptation to local conditions. Activities and programmes of the Food and Agriculture Organization of the United Nations in fields related to rangeland are briefly reported.

RANGE IMPROVEMENT OPPORTUNITIES

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Range improvement is defined as those structures and practices employed in the management of range for the purpose of maximizing the productivity of the system by providing the best possible range resource. Opportunities for range improvement are provided only by the manipulation of the physical environment, the vegetation or the grazing animal. The opportunities and procedures are different for sub-climax rangelands and climax rangelands. Fire can be used as a tool for range improvement in sub-climax rangelands but not in climax rangelands. Fertilization and amelioration of the soil is frequently a means for improving sub-climax rangeland but seldom for climax rangeland. Selection and breeding of superior range plants is an area of endeavour of great importance for achieving improved range. In such programs improvement of the genetic potential for quantity and quality of herbage is important in sub-climax rangelands while qualitative improvement is the overriding consideration in climax

rangelands. Procedures for introducing superior plants into rangeland need improvement. Fencing and grazing management are important tools for manipulation of special composition and so effecting improvement.

ECONOMIC CHOICES OF RANGELAND USES

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Grazing of domestic livestock on rangeland is a land use thousands of years old, and today the dominant use of a third of the world's land. Range users must be skillful ecologists, skillful livestock managers, and good marketers. The economic decisions on rangeland use include choosing optimum mixes and levels of inputs. Decision-making for rangeland use includes both individual and group decisions. Rangeland tenure often complicates the decision-making process, for tenure boundaries frequently do not coincide with ecological boundaries. In both group and individual land tenures there has been a persistent tendency to over grazing, with consequent loss of productive capacity. Rangeland is used for wildlife, tourism, recreation, and other uses. Demand for rangeland outputs will almost surely rise in the future.

HUMID TROPICS--A SLEEPING FORAGE GIANT

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Tropical areas in Latin America and elsewhere with potential for increased forage and cattle production are defined. Their improved productivity is dependent on adapted legumes and correction of nutrient deficiencies in the common leached acid soils. The important legumes and grasses are outlined, and their management in improved rangeland to lower costs is discussed. Vastly increased amounts of beef could come from the humid tropics, but it needs to be relatively cheap and good quality.

PANORAMA OF THE RANGELANDS OF NORTH AMERICA

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First introduced to eastern Mexico in 1521, cattle gradually increased in numbers during the next 300 years. By the late 1860s, southwestern Texas resembled a vast beehive from which cattle swarmed north and west to stock the grasslands only recently vacated by the Indian and the buffalo. Overland sheep drives brought sheep numbers to near record levels by the end of the century. Ranching was looked upon as being transitory in nature, the stockman only occupying the land until

it was needed by the homesteader. This fostered an attitude whereby the stockman tried to get as much as he could from the land as quickly as possible, which in turn resulted in severe overgrazing and deterioration of the range. By 1936, the forage value of more than 90 percent of the unreserved public lands had been cut in half and conservation laws, starting with the Taylor Grazing Act, were passed. Since then, systems of management and control to preserve and monitor the carrying capacity of the range have been instituted. Nevertheless, a significant percentage of the rangelands of western North America are still in only fair to poor condition and considerable improvement is possible.

Man and Biosphere Session

GRAZING LANDS AND MAN--MAB-3 INTERNATIONAL PROGRAM.

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Public interest in solving environmental problems has grown throughout the world. Man's knowledge about the biosphere in which he lives is often inadequate to cope with many of these problems or to assess their relative significance. The Man and the Biosphere Program is an intergovernmental effort to focus this research, public education, and technical training to fill this need. It is designed with full recognition that cooperative interdisciplinary research at local, regional, national and international levels is essential if pressing global environmental problems are to be solved. The distinctive feature of the program is its trans-disciplinary scope. The focus upon man-biosphere inter-relationships implies that it must draw widely from the methodological resources of both the natural (physical) sciences and the social/behavioral sciences. But though the methodological may be derived from disciplines of one kind or another, the goal of the program and the various subprograms is to seek the comprehensiveness that comes ultimately from trans-disciplinary conceptualization. The United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and the Biosphere (MAB) program is one of the youngest international scientific programs. Activities in MAB are guided and supervised by the International Coordinating Council (ICC) made up of representatives from 25 nations. A permanent secretariat located in Paris is responsible for carrying out instructions of the ICC. Particular functions are to stimulate and coordinate research and training activities and provide assistance to developing countries.

GRAZING LANDS AND MAN--U.S. MAB-3 PROGRAM

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Improving man's partnership with grazing lands is the focus of the Committee on the Ecology and Management of Grazing Lands, which is one of 16 committees making up United States participation in the worldwide Man and the Biosphere research program set up by United Nations Educational, Scientific and Cultural Organization (UNESCO). The U.S. Committee on the Ecology and Management of Grazing Lands has focused its attention on the use of these resources for the production of animal products such as meat, fiber and hides--while recognizing that there are other uses which must also be considered for any ecosystem. The primary objective of MAB-3 is to realize the production potential for each grazing area which utilizes the maximum sustained-yield where it is compatible with other human values. Three sub-objectives are identified

as follows: (1) To study the production capability of grazing lands, considering site characteristics, management opportunities, and present cultural practices. (2) To assess the animal production potential for each area and where that potential is not being reached, to assess the kind or kinds of animals needed to reach that potential. (3) To develop methods of technology transfers that insure the techniques for meeting (1) and (2) are transferred to the cultures of the peoples inhabiting grazing lands. This also requires that management techniques be compatible with the cultural characteristics of the areas.

POTENTIALITIES FOR IMPROVING RANGE MANAGEMENT IN MEDITERRANEAN COASTAL DESERT OF EGYPT

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Shortage of animal consumption in Egypt has continued to be an unsolved problem since World War II. Prices went up 30-fold while salaries were hardly doubled. This problem started in 1947 when the population was 20 million and now has become more complicated with a population of 40 million and with a loss of parts of cultivated grounds to urbanisation and industrialization. Attempts to ameliorate this situation were based mainly on restricted consumption and importation.

The main obstacles against increasing animal population are in short: lack of natural pastures, limited areas for irrigated pasture, and high cost of feed materials. Therefore, it becomes imperative to explore potentialities of deserts for pasture production. The western Mediterranean coast provides such potentialities and pilot schemes and experiments have been started in this area since 1918 for this purpose.

This paper reviews a major range project implemented at Ras-El-Hekma between 1954 and 1959, and attempts to distill from its experiences means of tackling range problems and of developing natural resources in this arid coastal area. This will enable assessment of available options: to improve herds or improve range plants, and whether improvement should be through introduction of species or through protection of endangered palatable nutritious over-grazed native species, or a combined solution of both. The degree of success of such projects depends on the consideration of the socio-economic pattern of bedouins, a component that should not be under-estimated.

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THE IMPACT OF HUMAN ACTIVITIES AND LAND USE PRACTICES ON GRAZING LANDS IN THE LOW-RAINFALL SAVANNAH BELT OF SUDAN.

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The Sudan with an area of 2.5 million km² has a population of about 17 million, of which one-sixth are nomads. Although the economy of the Sudan is predominantly agricultural, the agricultural resources are not fully utilized. The Sudan is characterized by vast plains interrupted by rolling country and a few widely separated groups of hills. The rainfall varies from 0 mm in the North to about 1,400 mm in the South, producing ecosystems varying from barren desert to closed tall forest.

During the last three decades a number of factors have been operating to bring about deterioration in grazing lands. These include the expansion of veterinary services, the provision of water by digging boreholes, grass fires, expansion in mechanized rain-fed and irrigated cultivation, the population increase, the Sudano-Sahelian drought, and the communal land use system.

Bitter experience seems to have taught the farmer and the nomad to evolve a system not only of farming and pasturing, but of social and ecological relations which minimize the risk. These attitudes and behaviors are largely responsible for the devastation of grazing lands.

There is a host of interacting variants that need to be recognized and analyzed when talking about carrying capacities and over-grazing, when advocating quality against quantity; when trying to convert the nomad into a farmer or rancher; when hoping to shift from subsistence to cash economy; when establishing the hierarchy of organization and authority; and when endeavoring to change traditional deficiencies into functional efficiencies.

IMPACT OF DIFFERENT LEVELS OF INTENSITY OF EXPLOITATION ON THE GRAZING LANDS OF SOUTHERN TUNISIA.

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The concerned presaharan regions of Tunisia are lying between 100 and 200 mm isohyets. The rainfall is concentrated during the cold period. The steppe vegetation is progressively being cleared, principally by cereal farming. The remaining cover becomes degraded through overgrazing. The main reasons are the increasing population and the tendency for the people, formerly semi-nomadic, to become settled.

From the observation of the past and actual state of the vegetation and soil, a method gives the foreseeable evolution for the next 25 years of the grazing lands (areas, biomass, production) under the influence of four different levels of intensity of human pressure in a selected zone.

RANGE PROBLEMS IN IRAN.

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Iran is presently facing natural resource conservation problems in more than 70 percent of the 165 million ha (628,000 mi²) of the entire country. The term "range" is defined, and based on this definition, a total area of 100 million hectares of fair to good, poor to fair and very poor to poor producing ranges has been estimated. In contrast, a rapid increase in livestock numbers with a significant shift from sheep to goats resulting in lower quality meat has been recognized since 1950.

Sixty-six million sheep units with 80 percent dependence on 100 million ha of rangelands leaves a shortage of 15 million tons of forage to overcome the feed shortage for more than 52 percent of livestock population.

In this study, the economic condition of villagers, semi-nomads, and administrative, social, economic and political problems affecting the range resource are analyzed and discussed. A solution to these problems through a nationwide educational effort and comprehensive range management planning program is suggested and accompanied by a proposed work schedule for the next five years.

EFFECTS OF FIRE ON THE VEGETATION AND SOILS IN KAINJI LAKE NATIONAL PARK, NIGERIA.

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This paper summarizes the effects of fire on floristic composition, herbage dry matter, and soils in the *Burkea/Detarium* vegetation at Kainji Lake National Park in the Northern Guinea savanna zone of Nigeria. The results indicate that late burning promotes the growth and development of perennial grass while early burning reduces perennial grass and encourages the growth of annual grass.

The percentages of dry matter burnt by late fires are higher than the percentages burnt by early fires. Early burning produces little or no effects on the nitrogen contents of the upper layer of the soils in the study area (0-10 cm), while late burning reduces the nitrogen content of the soil upper layer. Both the early and late burnings increase the soil pH, phosphorus, calcium, potassium and magnesium content of the upper 0-10 cm layer, while the lower 10-20 cm layer is rarely affected.

DESCRIPTION AND TRANSFORMATION OF THE AGRICULTURAL-PASTORAL ECOSYSTEMS FOR THE BENEFIT OF MAN IN BOLIVIA, CHILE AND PERU.

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In the Andean Region of Latin America, millions of inhabitants depend upon agricultural-pastoral activities which do not receive sufficient technical

or financial support. The related ecosystems are generally exploited, bringing about progressive degradation and reducing productive capacity, thus influencing economic and nutritional levels of the human settlements. Problems are described for several agricultural-pastoral ecosystems in Bolivia, Chile and Peru. These three countries have MAB National Committees which are cooperating with this MAB-3 project. Objectives of the project are to: (1) describe and determine the structure and function of the agricultural-pastoral ecosystems where the human activities occur, (2) develop and implement practical simulation models, (3) establish use and transformation alternatives in time and space, and (4) give practical socio-economic solutions for the development of human settlements.

WORKSHOP: SOCIAL PROBLEMS IN RANGELAND USE: SOCIAL SCIENTISTS SURVEY DEVELOPMENTS IN THEIR FIELDS OF INTEREST INVOLVING PASTORAL SOCIETIES.

Moderator WALTER GOLDSCHMIDT.
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For over 40 years, social scientists have worked closely with rangeland peoples, studying their means of animal and rangeland ecology, and articulation with non-pastoral groups. The recent drought in the Sahel, the need for increased animal production, and the threat of desertification have focused international attention on the development of rangeland peoples. Suggestions for development vary from livestock reduction to complete elimination of pastoral production. This session surveys the social problems arising from rangeland use. Tapping the experience of social scientists who have worked with pastoral societies throughout the world, three case studies highlight the more salient social problems occurring among rangeland peoples: (1) the Navajo stock reduction, (2) an innovative scheme for rangeland development from Syria, and (3) an unusual development project in Tunisia. The specific problems reviewed include traditional solutions to rangeland problems, market articulation, human and animal population dynamics, and others. The session is designed for the non-social scientist who wishes to know what contributions the social sciences are making to solving contemporary rangeland problems.

TUNISIAN PRESAHARAN PROJECT: I. ECOLOGICAL IMPLICATIONS OF CULTURAL CHANGE.

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Although the most common stereotype of arid lands is that of low biological productivity, an equally important and less stressed characteristic is their spatial and temporal variability. Precipitation, and therefore productivity, are more variable in such areas than in any other major, biogeographic type.

Arid areas are capable of supporting some use in periods of precipitation, but are vulnerable to damage in the frequent periods of drought. Nomadism, both in human cultures and in wild animals, has evolved as a mechanism for moving about to locales that received

precipitation. This pattern has a two-fold value: it ensures sustenance for the exploiter, and provides rest for the producers during sensitive, dry periods.

Sedentarization of North African nomads sedentarizes pressures on the land. Pastoralists must graze the same locale year after year, whether or not it has rained and whether or not the ecosystem can maintain that use. When sedentarization is combined with growth in populations and livestock numbers, the result is progressive degradation of the ecosystem and its productive capacity.

Stocking rates of livestock in southern Tunisia today exceed those of North American areas with the same rainfall. Density and productivity of vegetation declines; wind erosion of soil increases and the process could appropriately be termed desertization.

The present land-use patterns may be transitional, and several alternative use patterns and economic policies could both halt the degradation of the land and improve the lot of the people.

ECONOMIC ALTERNATIVES FOR A SEMIPASTORAL POPULATION IN SOUTHEAST TUNISIA.

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Industrial systems have a large impact on rural economies when the two come into contact. The form of resulting culture change in the rural area may vary greatly among human populations. Local factors that influence particular behavioral responses of a rural population are: values and goals, the characteristics of the local ecosystem, social organization, and demographic patterns. New economic alternatives may or may not be accepted by a rural population depending on the relative costs and benefits of each alternative. Goals, values, and other local factors determine the desirability of the new benefits and the acceptability of the respective costs. It is suggested that new economic alternatives will be adopted by a population if the new system provides a higher ratio of energy benefits to costs than the existing economic system. New alternatives will not be adopted if aspects of the new alternative are incompatible with local goals and values or if the family does not have access to sufficient land to practice the alternative.

South Tunisians have begun to shift from a semi-pastoral subsistence economy to a system of partial dependence on seasonal wage labor opportunities in nearby urban areas. This study explores the influence of values and goals on the decisions of these people to adopt or reject this new economic alternative. In order to accomplish this, a study of energy flow was conducted during two successive annual agricultural cycles between 1973-75. Observations were made on energy production, consumption, and expenditure by families practicing either of two existing economic systems. The energy flow approach permits quantification of the energy benefits and costs of the semi-pastoral subsistence system on which the population depends.

The energy benefit to cost ratio of two existing South Tunisian economic patterns and of two hypothetical patterns is determined along with the pattern's implications for the rural value system. The data show that a system having a higher energy benefit-cost ratio is in fact rejected by the semipastoralists due to aspects of the system that make it unacceptable in terms of local values and goals. These results have implications for attempted programs of planned eco-

conomic change and for programs of range management. The Tunisian example illustrates the ability of the energy flow approach to evaluate (in an energetic "cost-benefit" framework) the feasibility and potential acceptability of programs of planned economic change or ecosystem management before they are implemented.

This research was supported by a PHS-NIGMS Pre-doctoral Traineeship in Human Biology (Training Grant 5 T01 GM0-1748) administered by Paul T. Baker, and by a Smithsonian Institution grant (SFG-2-3492) to the Tunisian PreSaharan Project, Frederic H. Wagner, principal investigator.

Section 1. Sociological and Political Aspects of Rangeland Resource Management

RANGELAND--THE UNRECOGNIZED RESOURCE IN WORLD FOOD PRODUCTION SYSTEMS.

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Much has been written in recent years and much rhetoric has taken place about the serious nature of the world food problem. While it may seem logical that the focal point of these discussions has been on the world's "cultivated land base" and on "grain production" as the measures of food security, this simplistic approach tends to ignore the very significant role of rangelands and the contribution of grazing animals -- both domesticated and wild -- to world food production. This lack of understanding was apparent at the World Food Conference in Rome in 1974 and has continued to persist in our literature base. As a result, little attention has been given to re-directing our research efforts or to strengthening our education and extension systems as they relate to this vast non-cultivated land resource.

The world's largest land resource is range and pasture. The United States alone has about 1.5 billion acres of range and pasture land -- areas not primarily adapted to crop production or to other intensive land use. The range resource is characterized by rough topography, poor soils, severe temperatures, or lack of sufficient moisture to sustain cultivation. In general the per-acre income is low, but the total contribution to the economics of many countries, due to the vast acreage involved, is highly significant. It has been estimated that over two-thirds of all feed required by domestic livestock in the U.S. is derived from grazing lands. In many areas of the world, vast societies are sustained almost entirely by the income and products of grazing animals. And, while participants in the Rome Conference talked about the shortage of "grain," the major impact of the drought in the African Sahel was tied to the lack of "forage" production on range lands.

Many of us thought we had realized a "dream come true" when the world became "ecology conscious." We thought that now, perhaps, the scientific community would see the need for more research on large range "eco-systems"-- that the world would now take steps to analyze vegetation change and man's role in the environment. These dreams have, for the most part, been unrealized.

With the passage of Title XII of the Foreign Assistance Act of 1975, which places new emphasis on research and education in the international setting, it is my hope that the world's range land will eventually be adequately recognized. Perhaps this conference will help re-direct attention to this resource, not only in the national setting, but in the broad context of world food production.

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SOCIOLOGICAL ASPECTS OF PASTORAL LIVESTOCK PRODUCTION IN AFRICA.

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Large parts of the African range are claimed and used by pastoral societies. Current development efforts in the African pastoral sector often are planned in ignorance of traditional pastoral production and disregard of the implications of innovations on the societies concerned. ILCA's study of animal production systems include the basic structure of the society, its resources and value standards, its production regime, including the decision making processes, the livestock management practices and the impact of management decisions on the production constraints identified with the main focus on the dynamics of the production system, especially the inter-relationships among and within sub-sets of people their animals and within their deteriorating environments and where their population is even increasing.

Preliminary results in the Niger Delta/Sahel region of Mali show that five groups (The Delta Fulani, The Sahel Fulani, The Maures, The Tenants of the Office du Niger and The Livestock Traders) compete for resources, and that the adoption of the different groups are based on seasonal exploitation of different areas, combinations of economic activities and linkage to a marketing system that connects them to the national economy. The alternatives to successful introduction of innovations are, over the long-term, decreased in or at least the stagnation of the animal and human populations.

AN EXAMINATION OF THE HISTORIC RANGELAND USE SYSTEMS OF THE OGLALA SIOUX INDIANS AS INFLUENCED BY THEIR SOCIAL CUSTOMS.

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Historically, the original landholdings of the Oglala Sioux extended throughout the Great Plains area. These massive land areas were subsequently diminished through congressional treaties and policies. Moreover, it was the Allotment Act of the 1880's that promoted a cycle of drastic change in societal views regarding the status of lands and their useage. Overall, these policies gave impetus for land to be viewed as a valuable commodity that a changing culture could utilize effectively in their new economic system.

Interestingly, during those early reservation range-land use systems, the Oglala Sioux people maintained a high level of self-sufficiency with abundant herds of animals and community gardens. Progress was sharply offset when heirship status lands created a new method

of ownership and a mammoth proportion of problem areas. As a result of this combination of sociological and political impact upon 2.5 million acres of grasslands, there has been a declining development of viable agricultural Indian lands. Only very recently has the tribal government become involved as a landholding corporation in a rangeland use system. It may be reiterated that self-sufficiency will be regained only when such a system is compatible to social customs.

MANAGEMENT OF RANGELANDS IN KENYA TO INCREASE BEEF PRODUCTION: THE SOCIO-ECONOMIC CONSTRAINTS AND POLICIES.

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The Rangelands of the Republic of Kenya comprise some 490,000 km² equivalent to 80 percent of the country's total area of 585,000 km².

The people of the range areas, who number two million, own 50 percent of the nation's flocks. Made up of an estimated 5 million cattle, 6 million sheep and goats, and one million camels.

Much of Kenya's livestock production in range areas is carried out by sedentary and/or nomadic pastoral people who have traditional ways of doing things. Significantly, this involves grazing on open rangeland; a complete absence of grazing control, except the ones forced on them by drought; a natural tendency to increase stocking rates to support an increasing population; and a system of overstocking whose effects are very serious during the periods of limited rainfall. Grazing management and control has thus remained the weakest point in the livestock development effort.

Kenya's current agricultural policy, including livestock development, is culmination of policies and attitudes initiated at varying stages during the colonial era. These have contributed to the present structure, performance and problems of the agricultural industry.

The effect of the policies on livestock development cannot be quantified, but the impact is easily felt; it tends to hold down output and increase meat consumption in the country.

A Livestock and Meat Industry Development Study conducted in the country in March 1977, concludes that, based on current policies, there will be a very large gap indeed between quantity demanded and supplied of livestock in the country by 1990, unless some of the current policies are changed, including a real price increase; that is, a 20 percent price increase coupled with annual real price increases of one percent from 1980 onwards, and with no increase in real rural incomes.

SOCIOCULTURAL RESEARCH FOR PLANNING AND MANAGEMENT OF A NEVADA BUREAU OF LAND MANAGEMENT GRAZING DISTRICT

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This report considers sociocultural research conducted in 1976 for the U.S. Bureau of Land Management by a cultural anthropologist.

The research described the sociocultural groups and values of the people of the Winnemucca District, Nevada. There are several major ethnic groups in the district (Basque, Indian, and Mexican). A second kind of classification of people is used by residents who consider it important to recognize the length of time people have lived in the local area. Values held by district residents emphasize personal identification of people and face-to-face interaction. Individuality and self reliance are admired, and continuity is very important.

An unexpected result of the research was discussion and agreement by district and state office staff and the researcher that there must be more staff training in "people management" rather than just resource management. Some recommendations are made to modify sections of the Bureau of Land Management, Planning System Manual for easier application of sociocultural data, and it is suggested that a state supplement be prepared to consider Nevada sociocultural conditions.

SOCIO-POLITICAL PRACTICES HINDER IMPROVED RANGE MANAGEMENT.

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Lesotho is a small kingdom in southern Africa with low agricultural production, severe erosion, overgrazed rangeland and many people. Agriculture is the major natural resource suitable for development. Nearly 85 percent of the land is in range use, and simultaneously with livestock, offers the greatest improvement potentials.

Cattle posts, mostly in the mountains, cover about 45 percent of the country. Their grazing is administered by Principal Chiefs, who encounter difficulty enforcing stocking limits recommended by Ministry of Agriculture. Outside the posts land allocation and grazing is controlled by lesser Chiefs. Free grazing on rangeland and crop aftermath encourages livestock ownership.

Livestock is kept mainly for investment, personal security, satisfaction of ceremonial need, and for draft animals. Donkeys transport supplies and produce. Horses are for riding, rarely for draft. Milk production is low. The value of exported wool and mohair has been slightly higher than live cattle and sheep.

Changes are proposed to overcome social and legal constraints with minimum effect on the culture. Essentials are alternatives for investments with better returns, security for aged, and economic incentives to make land and livestock more productive. Income is needed from the main natural resource for village improvements and government services.

SOCIAL AND INSTITUTIONAL BARRIERS TO RANGELAND MANAGEMENT INNOVATIONS.

BERNARD SHANKS.

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Rangeland resource management in the United States is fragmented by private land ownership patterns and by federal and state land use practices. Rangeland managers are often isolated geographically and socially from wildland recreationists and other non-consumptive users of the public rangeland. Survey research results indicate that rangeland managers are relatively uninvolved with professional organizations when compared to other federal land managers. Indications are that public range managers in the United States and elsewhere accept and apply new rangeland policies and programs slowly.

Several institutional and social problems are inherent in the existing public land management framework. First, rangeland management responsibility is scattered among several agencies. Second, there are wide differences in training and professionalism of range managers. Third, social and educational backgrounds of managers have enhanced a conservation approach to ordering rangeland activities.

Several specific institutional changes can be recommended to assure more responsive public land range management. Professional organizations and the field managers would benefit from an understanding of the social sciences and interpersonal training could enhance an understanding of urban based rangeland users. Primary barriers to improved range management are probably social and institutional rather than technical or biological.

FULANI NOMADISM AND HERD MAXIMIZATION: A MODEL FOR GOVERNMENT MIXED FARMING AND RANCHING SCHEMES.

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I describe a Nigerian pastoralist adaptation which suggests that many current attitudes about nomadism (the regular pattern of physical movement from region to region) are unfounded. Further, the belief that nomadism is inefficient is resulting in mixed farming and settlement schemes that demand unnecessary and disruptive transformations in the characteristic pastoral way of life. I propose to show that the traditional mobility patterns of the Fulani of Bokkos, Nigeria, have enabled these herdsmen to maximize their human and herd populations in multi-ethnic settings without causing environmental destruction or social conflict. Government planners concerned with efficiency should be aware of the "safety valve" function of nomadism not only among traditional societies but for the ranching complexes they envision for the future.

One of the most unique pastoralist adaptations occurs in Bokkos, Nigeria, which is located on the Jos Plateau in Benue Plateau State. In contrast to most pastoral nomads the Bokkos Fulani do not reside at the margins of farmland but rather they inhabit and pasture their cattle on the fallow plots of farmers of the Ron agricultural tribe. In this environment the upper limit of population expansion is clearly defined. Complicating population control is the favorable nature of the Bokkos environment for cattle rearing. In particular, reciprocal ties with

farmers centering on the exchange of manure for free farm labor has enabled herdsmen to experience sizeable annual herd increases. In spite of more than 50 years of expanding herd populations, few cases of environmental destruction or social conflict have been reported. The evidence suggests that the Fulani traditional patterns of nomadism have enabled the herdsmen to continue their expansion while still maintaining the ecological balance in Bokkos.

AN OVERVIEW OF LAND TENURE AND ADMINISTRATION IN AUSTRALIA'S RANGELANDS.

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The five states that contain Australia's rangelands have adopted different systems of land administration and tenure in an attempt to solve the problems faced and caused by Australian pastoralists. Three methods of control-persuasion, manipulation and regulation are used to influence land management. Restrictions have been placed on the area of land that may be managed by one person, and, in two states, there have been conscious attempts to subdivide the land and settle more people on it. This has created a large number of sub-standard holdings and continual need for rural reconstruction.

REVIVAL OF THE "HEMA" SYSTEM OF RANGE RESERVES AS A BASIS FOR SYRIAN RANGE DEVELOPMENT PROGRAMME.

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The "Hema" system of range reserves has been described as the world's oldest effective range conservation system. Developed in Saudi Arabia it proved applicable in many countries of the Middle East.

Facts revealed by the author on this system have been carefully utilized in planning of the Syrian Range Development Programme. The "Hema" has been modified in the form of Range Cooperatives to become an effective working tool in modern conditions of life.

Twenty two Hema Coops have been established within the Syrian Steppe, covering 1.5 million ha., introducing range protection and conservation practices in replacement of nomadic uncontrolled grazing. This stimulated initiation of 53 Sheep Fattening Cooperatives to control increase in sheep numbers through sheep offtake. Eight Government Range and Sheep Centres have been established at different ecological regions for experimental, training and extension purposes. Fodder legumes have been successfully introduced through Range and Fattening Coops to replace fallow in the traditional wheat/fallow rotation. Legislation prohibiting ploughing of marginal areas have been passed and enforced. Supplementary and emergency feed reserve have been established through formation of National Feed Revolving Fund and establishment of a network of feed warehouses. As-

experience of UNDP/FAO/WFP and World Bank is described; and the possibilities of applying that experience in the Arabian Peninsula discussed.

THE HISTORY AND PRESENT PATTERN OF PASTORAL RANGE PRODUCTION IN NEW ZEALAND.

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The initial pastoral settlement of the open tussock country of South Island, New Zealand, a century and more ago was followed by a rapid increase in livestock numbers to the end of the 19th century, followed by a decline that generally continued until recent years. The political and sociological aspects of these changing circumstances are traced along with the ecological deterioration that accompanied them. Changes in tenure introduced in mid century led to the adoption of range development practices which became available with improved scientific understanding and technology. The further technological development of the range resources for pastoral purposes is examined against the background of current social, political and economic forces at work in the tussock grasslands and mountain lands.

"THE ZUNI RANGE CODE" ONE INDIAN TRIBE'S TRANSITION FROM A TRADITIONAL CUSTOMARY LAND USE SYSTEM TO A SELF-IMPOSED REGULATORY SYSTEM.

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By authority vested in the Secretary of the Interior by 25 U.S.C. 48 (R.S. Sec. 2072), Act of 1834 (revised 1964), the Secretary entered into a Program Agreement with the Zuni Tribe in May 1970, authorizing the Zuni Tribal government to "take over" the direction and management of their own affairs. This "Program Agreement" was considered a pilot study which ultimately led to the development and passage of P.L. 93-638 December 1975.

This law granted authority for organized Indian tribes to "contract" for services formerly administered by the Bureau of Indian Affairs. The Zuni Range Code's development was initiated, completed and approved over a period of three years. It is presently being implemented by a committee of tribal land users. The Code provides for the preservation and protection of tribal resources, interests, and rights; and for an equitable distribution of the tribal land resource through administration of grazing privileges; and, satisfies the tribe's obligation to the Secretary of the Interior (Trust Responsibilities - C.F.R. 25 - Indians). This transition of grazing use is a commendable milestone of progress for the Zuni Tribe.

THE PROCESS OF CHANGE IN CERTAIN LIVESTOCK OWNER AND OPERATING GROUPS IN THE WEST AFRICAN SAHEL.

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The typical stockman of the western zone of the African Sahel region is a rational, goal-oriented person, living and operating in a well-organized social system. His willingness to make changes and/or reaffirm established practices is tempered by the degree to which an alternative is consistent with norms and values of the social system and with the goals of the authority figures of the system. The Sahelian stockman relies heavily on professional tension management, including prayer and magic, covering periods between the decision to change and the payoff from change. External change agents, who are classified as intruders in the social system, should channel their messages so as to facilitate the flow of information and to enlist the support of authority figures, including chiefs, notables and family heads, and tension management specialists, including religious leaders.

RANGE TECHNOLOGY MUST BE EXTENDED.

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Research and newly developed technology are lost if they are not extended to and adopted by the user, whether it is the private land owner or public land manager. The Texas Agricultural Extension Service makes research findings of the Texas Agricultural Experiment Station and information from the resident teaching staff of Texas A&M University available to livestock producers and landowners through in-depth educational programs conducted by County Extension Agents and Specialists.

Educational needs are determined by broad based committees composed of laymen at the local level. The County Extension Agent coordinates planning and conducting of in-depth educational programs, which involve many informal teaching methods. Specialists adapt and make available the latest technology and information to County Agents for use in producer and landowner programs. Problem areas needing additional research are in turn pointed out to the researcher.

FEDERAL AND STATE COOPERATION FOR IMPROVING RANGELANDS THROUGH EDUCATION.

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The Old West Regional Range Program is a recent effort in the United States to improve the productivity of a large range area. The area encompasses the states of Nebraska, South Dakota, North Dakota, Montana, and Wyoming--members of the Old

West Regional Commission. The Commission is one of several regional groupings of states authorized by Congress to resolve regional economic problems.

The Old West Regional Commission contracted with the Society for Range Management in 1975 to administer a range management educational program over a two-year period. Objectives were to: (1) provide the power and materials for accelerating range management education, (2) provide the impetus for a continuing program to benefit the Region's livestock industry, and (3) gain public recognition of the value of the Region's range resources. Those objectives were designed to assist the states with long range goals aimed at getting a high percentage of all ranges and pastures under some form of intensive management to improve range condition, forage quantity, livestock watering facilities, wildlife habitat, and recreation.

Program activities and measures of success will be discussed.

THE COMMUNICATION OF RANGE MANAGEMENT TECHNIQUES TO NOMADIC PEOPLE.

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In Kenya about 4/5 of the total land area is rangeland. This land is occupied mainly by different tribes of nomadic pastoralists. These people regard cattle as wealth and the resultant overgrazing is turning potentially good rangeland (500 mm rainfall per annum) into desert.

The Challenge: Can nomadic pastoralists be transformed into progressive ranchers? How can illiterate people learn about range management techniques? Which are the really essential techniques to be concentrated on?

Considerable experience has been gained with the Maasai and Samburu tribes introducing better livestock (Boran and Sahiwal cattle and Dorper sheep). Demonstration ranches of 800 ha each have been set up in three different places. Visual teaching has helped to create an interest in ranching. Communicating techniques to do with the living animal have been reasonably easy. Communicating at a deeper level the importance of land as a national resource has proved difficult.

Conclusion. The desert in Africa is advancing and many countries have experienced the heartbreak of famine. Range management techniques are known that can improve the situation. The human factor is the most difficult to influence. The future of the rangelands in Africa revolves around successful motivation of the nomadic peoples.

TEACHING RANGE BY RESULT DEMONSTRATION.

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Rangeland managers vary in technical training and breadth of experience to make management decisions about new techniques. Practices locally applied and evaluated personally by managers are more credible and

easily fitted to ranch resources than practices seen elsewhere or appearing in industry journals and magazines.

Result demonstrations, in which research proven practices adhering to known principles are extended to local field situations, underlie the success of range Extension educational programs in Texas.

Result demonstrations are locally planned and implemented by teamwork among county Extension agents, local landowners and managers, and range specialists. The ranchmen on whose operation the practice is applied is involved in all phases of planning, evaluation and interpretation to neighbors. Such personal involvement in application of research and the realization of results insures a broad diffusion of changing technology.

Result demonstrations help establish an understanding and trust between the Extension Service personnel and local ranchmen. New problems are identified and strategies planned for their resolution through application of current research, further extension of known practices and initiation of new research to meet the challenge.

Result demonstrations on rangeland fertilization in Texas have led to more attention to range forage quality and needs to supplement the diets of range animals. Ranchmen have learned to consider both vegetation and livestock in adapting new practices for more efficient and profitable ranching.

The principle of land user involvement in all levels of planning and evaluation of range management application is an important ingredient to Extension education and diffusion of technology in other environments with varied cultures.

A CASE FOR INDIGENOUS PARTICIPATION IN RANGELAND DEVELOPMENT.

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The Colombian and Venezuelan llanos are an important but underdeveloped, grasslands region. Despite hundreds of years of European settlement, the area remains a frontier; a political, social and economic backwater. During the colonial period large herds of cattle thrived in zones inhabited principally by Indians today. Currently stock raising is important only in parts of Meta, Arauca and Apure. Large ranchers tend to exploit the land exclusively for pasture, to the detriment of the regional economy. The more numerous small homesteaders barely subsist by slash-and-burn cultivation. The surviving indigenous population has been either ignored or, at best, subjected to an informal policy aimed toward transforming them into sedentary homesteaders. This approach has been spectacularly unsuccessful.

This paper suggests that Vicnada, the section of the Colombian llanos which is least developed and poorest in natural resources, should be the center for a model rangeland development project. The Guahibo Indians, as the largest population of the region, are the most likely to adapt to and benefit from new ideas of rangeland management.

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ISLAMIC LAW AS A FACTOR IN GRAZING MANAGEMENT: THE PILGRIMAGE SACRIFICE.

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It is widely held by Doctors of Islamic Law that Muslim households all over the world are obliged to sacrifice an animal, preferably male and preferably a sheep, with a goat as best alternative, on the day when pilgrims at Mecca commemorate Abraham's sacrifice of the ram caught in a thicket - a festival that recurs once every lunar year of 354 days. This creates a large and selective demand for livestock in addition to that which arises from nutritional needs. The peak herd size is reached at a date unrelated to biological cycles of plant and animal development and to the carrying capacity of grazing land. The resulting constraints add greatly to the difficulty of rangeland management. A study of the relevant texts shows that this sacrifice is not required by the Holy Koran, which is the fundamental source of law: it is based on passages in later and less sacred books, whose interpretation is open to debate. Any easing of the requirements pronounced by the religious authorities of the various Muslim countries could make a valuable contribution to management and conservation.

AVOIDANCE OF GRAZING ON THE SOUTHERN MARGIN OF THE WEST AFRICAN SAHARA.

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The Sahelian zone of West Africa suffers from overgrazing by cattle and overcropping by arable farmers. The removal of vegetation by the activities of man appears to be causing a southward shift in the position of the Intertropical Convergence Zone, so that rainfall occurs further south, thereby extending the desert.

Important general factors in the process are the economic development of coastal towns and effective disease control programmes. A more specific causative factor is the increase in herds in the Sudan and Sahelian zones; this is likely to be extended greatly by tsetse eradication programmes planned by the international organizations.

It is argued that the desert will increase so long as economic pressure is placed upon it: the trend could however be reversed if cattle production in the Sudan and Sahelian zones were decreased. Loss in production could however be made good by increased use of the high forest zone. Cattle management in this area would involve problems of disease control but would involve increased production without the land degradation and climatic change associated with nomadic grazing at the desert margin.

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MILK AT THE EXPENSE OF MEAT: THE DILEMMA OF THE AFRICAN PASTORALIST.

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In many African countries off-take from the national herd is low. The poor productivity is attributable to seasonally inadequate levels of energy, phosphorus and protein in the fodder. Husbandry practice, particularly milking, exacerbates the problem because the pastoralist requires the milk for his own use or for sale and the milk is often part of the remuneration of an employed herdsman. The removal of only one litre of milk can leave insufficient for the calf and contribute to the high calf morbidity and mortality. Lactations are frequently extended and result in long calving intervals. The poor calving rate and the high calf mortality together result in an annual recruitment of weaned animals to the herd numbering one-third of the breeding females, which total 46-48 percent of most herds. The subsequent growth of these immatures is slow because of periods of poor nutrition.

Recognising a continuing necessity in most pastoral economics for some milk, the adoption of new techniques could mitigate the adverse effect of milking on the production of meat.

RANGELAND UTILIZATION IN THE REGIONAL CONTEXT: THE GOAT HERDERS OF THE NORTHERN PERUVIAN DESERT.

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This paper examines the goat herders of the northern Peruvian coastal desertic rangelands and shows their changing position in the rangeland ecosystem and in the regional economy. Herders rely on three sources of fodder: (1) native perennial vegetation, particularly *Prosopis chilensis* thickets occurring in areas of high water table, (2) sparse annual grasses, and (3) stubble and agricultural byproducts in irrigated oases. Changing agricultural and economic conditions have altered the relative abundance of these three, affecting the rangeland management techniques and accelerating the deterioration of the range. Increasing population in the oases and increasing demands for cash crops have led to an expansion of irrigation increased cotton and rice production. These crops have byproducts suitable for fodder. Increased population levels have led to an increased demand for fuel, including firewood, bringing about the destruction of the *Prosopis* thickets, a reduction of the water retaining capabilities of the soil and a decrease in annual vegetation. Goat herders have come to rely increasingly on the third fodder resource. However, fluctuations in agricultural production due to variations in available water and demand lead to periodic increased use of remaining *Prosopis* thickets, accelerating their decline. Rangeland management practices, therefore, depend in part on agricultural practices, and they must be seen in the context of the regional economy. Parallels are drawn between the expansion of the Peruvian coastal desert and the formation of the African Sahel.

NOMADISM AND RANGE MANAGEMENT IN THE SUDAN.

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Long term planning for conservation and management of renewable natural resources was investigated for the Savanna region of the Sudan. This region is currently subjected to intensive exploitation practices including shifting cultivation, unplanned grazing, fire hazards, and illicit wood-cutting. The main causative factors for the deterioration in the vegetation cover are attributed mainly to: (1) increased human and animal population pressure, (2) lack of proper management practices, (3) unplanned expansion in economic activities ancillary to mechanized and traditional agriculture, (4) lack of effective extension services necessary for the enlightenment of the agrarian society about the significance of conservation of renewable natural resources, and (5) lack of policies, options, and strategies.

These factors are not only potentially destructive to the economy of the Sudan, but also inhibiting to the prosperity of the Savanna population.

The present national project involves: (a) proper surveys to study vegetation, soil topography, and climate as a means of site classification and land capabilities, (b) establishment of demonstration farm and employment of various mass media for the gradual diffusion of information pertinent to conservation of natural resources; and (c) development of light industries to absorb the milk and meat products of the area.

The socio-economic impacts of the project are discussed.

INCREASING ANIMAL PRODUCTION IN MOROCCO (NORTH AFRICA) THROUGH RANGELAND RENOVATION AND ANIMAL MANAGEMENT.

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Range lands make a major contribution to the agricultural resources of Morocco, (North Africa) with livestock production representing more than 50 percent of the total agricultural production of this area. Range management practices such as improved grazing systems, improved animal health programs and range renovation can make an important contribution to greatly increasing livestock production in this region.

A grazing study for ewe-lamb meat production was initiated in an arid Mediterranean climate (300 mm annual precipitation region of Morocco to compare: (a) improved flock management on a 2½-year-old Fairway crested wheatgrass (*Agrippon cristatum* (L) Gaertn.) stand seeded into native sagebrush range-rotationally grazed; (b) improved flock management on native sagebrush range-rotationally grazed and; (c) traditional management on native sagebrush range.

During the six-month grazing trial (April to October), the ewe-lamb flock weight gain production from the improved flock management on properly grazed native sagebrush range seeded to Fairway crested wheatgrass was 45.7 kg/ha vs. 16.0 kg/ha gain from the improved flock management on native sagebrush range and 9.0 kg/ha gain on native sagebrush range from the traditional management. This demonstration on range management practices for increasing animal production has provided impetus for increased activity in range renovation in Morocco.

Section 2. Rangeland Economics and Management Planning

IMPORTANCE OF RANGELAND RESOURCES IN THE ECONOMIC DEVELOPMENT OF THE SUDAN.

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The economy of the Sudan is based almost entirely on agriculture and land is the country's primary resource. Not only is the Sudan's economy an agricultural one, its agriculture in turn is virtually limited to a single crop, cotton. The financial dependence of the government on a single crop with a variable earning power puts the Sudan in a constantly vulnerable position. Recognizing this and in its concern for economic development, the government has started developing the rangeland resources which comprise 61 percent of the total area of the country.

Of the four main grazing regions, desert, semi-desert, savannah, flood plains, the savannah region is the largest in area and the one with the highest potential. Utilizing foreign capital, especially petrodollars from rich Arab Nations, an extensive plan is being drawn for developing big ranching operations in the savannah region. Foreign capital and technical assistance will also be used to solve problems facing the development of the rangelands in the other regions.

The future of Sudan lies in the development of its vast rangelands whose products have ready and close markets in the Middle East and Europe.

THE SIGNIFICANCE OF RANGELANDS OF ARAB STATES IN ANIMAL PRODUCTION.

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The arable land in the Arab states, as a whole, is restricted to about 5 percent of the total area. On the other hand the Arab states possess a vast area of rangelands, around 400 million hectares, or 30 percent of the total area. The efficiency of these rangelands varies with the ecological conditions. The carrying capacity of animal units varies from 3-5 ha/animal unit in the Atlas area in Morocco to 50-75 ha/a. u. in the desert zones of the African Sahara and Arabia peninsula. Those rangelands support almost 80, 50, 10 and 25 million head of sheep, goats, camels, and cattle, respectively, by the traditional nomadic tribal systems. This animal wealth has very significant impact on the economic and social life of 50-80 percent of the citizens of several Arab states.

For a long time the Arab states did not give except official service for nomadic communities. Recently the national plans in each state have taken a particular interest in the development of the rangelands and animal production. Investment projects are under

study and implementation all over the Arab states for the modern use of the rangelands, marketing and processing of animal production.

CONSTRAINTS TO IMPROVEMENT OF RANGELAND AND LIVESTOCK IN THE CENTRAL PLAINS AND CENTRAL PLATEAU OF MOROCCO.

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Morocco occupies the northwest corner of the African Continent and has a rich and varied history of livestock production. Frequent migrations and changes in occupancy of the land were common before the French Protectorate was established in 1912. Under these uncertain circumstances livestock ownership was a more stable investment and livestock husbandry was more attractive than crop production.

Many years of mismanagement and overstocking reduced forage production in Morocco. Grazing intensities are three to seven times the actual carrying capacity. This has resulted in the destruction of most of the native perennial grasses. Lack of forage is the principal limiting factor to livestock production, and the majority of animals are undernourished.

Wealth and prestige are measured in numbers of animals with little attention being given to saleable increase in weight and meat products. Ironically as the rangeland deteriorates more animals are crowded on the land to offset the population and the ever increasing demand for meat.

Relatively little effort has been made to improve the forage supply by improving rangeland or by sowing improved species. The system of tenure and land use leaves little incentive for improvement of the grazingland. In addition to facing extremes in climate, the producer must contend with insufficient capital, land, technical understanding, and religious factors.

SOCIOECONOMIC PRESSURES ON THE AUSTRALIAN RANGELANDS GRAZING INDUSTRY, AS A POTENTIAL EARLY WARNING SIGNAL OF RESOURCE DEGRADATION.

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Australian rangelands are briefly described biogeographically and statistically and their National production significance is evaluated. The decade

1967-1977 is examined, and is revealed to have been one of dramatic socioeconomic change of historic significance to Australia's grazing industry. Discussion of the "Decade of Change" as it affects the social, financial and management structure indicates the emergence of an industry problem, hitherto non-existent and described as a "Hard Core Debt".

Further probing of the problem demonstrates the inevitable transmission of this financial and social stress directly to the rangeland resource. By enquiry into the financial position of individual industry operators, simple financial/production demand analysis techniques are then employed to identify and define the symptoms of Hard Core Debt emergence.

The paper illustrates the potential of using socioeconomic surveillance for Hard Core Debt diagnosis on an individual or regional basis, as an early warning signal of potential rangeland degradation

ECONOMICALLY OPTIMAL SPECIES-MIXES AND STOCKING RATES FOR UNGULATES IN SOUTH AFRICA.

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Recent advances in the understanding of African hoofed ruminant communities have suggested that species compete and interdepend to varying degrees, thus refuting the hypothesis of non-overlap of diets. Productivity and profitability therefore do not necessarily increase with number of species. The choice of wild and/or domestic species, their proportions and their total amount become important in production operations. A method is proposed for optimising economically in simple systems. The shortcomings of previous methods (e.g. units of measurement, impracticability, and insufficient appreciation of the dynamic interaction between animals and their habitat) are minimised. However, economic optimisation increases rapidly in theoretical complexity as the number of animal species increases, and is probably beyond experimental determination for four-or more-species systems. The economic superiority of multi-species over simple systems must be substantial if the former are to become popular. Comparative profitabilities of simple and multi-species systems must be qualified by estimates, of known repeatability and tested reliability, of animal densities and range condition, and their changes in time.

THE UTILIZATION OF HIGH ALTITUDE GRASSLANDS IN THE SOUTH CENTRAL ANDES.

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The Central Andes are characterized by a high altitude grasslandscape running from north to south at the top of the mountain range. This lofty plateau forms two different production zones determined by altitude above sea level. The highest is located from an elevation of 4,000 m to the end of the continuous grass cover, and can be used only for the herding of sheep and alpaca. The lower zone (circa 3,000 to 4,000 m) is an area of mixed herding and agriculture (sheep, llamas, cattle, potatoes and barley). This

paper briefly describes these production zones and the manner of their utilization. It also deals with their relationship with one another, and their place within the vertically ordered resource configuration of the Andes. A brief description will be given of the role of high altitude range land utilization in both the modern market and the traditional peasant barter economies

COMMON-PROPERTY RANGELAND AND OVERGRAZING: RESOURCE MISALLOCATION IN BOLIVIAN AGRICULTURE.

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Accelerating damage to mountain ecosystems in the developing countries and subsequent reduction in food production capacity have been documented. However, little has been done to explain the consequences of man's exploitation of mountainous regions in terms of socioeconomic variables.

This paper presents an economic interpretation of the deterioration of rangelands in the Bolivian Andes. The burden of the paper is that overgrazing, consequent depletion of the range resource, and flooding and erosion are explained by utilizing rangelands as common-property resources with no public or private controls or restrictions.

Nominally, property rights to mountain rangelands exist but are not enforced. Evidence indicates the consequences of grazing Bolivian rangelands in common are (1) relatively low and declining levels of range productivity, and (2) accelerated erosion and serious flooding both in the rangeland and adjacent lowlands.

The principal policy implication is that property rights must be given and enforced in such a way that grazing intensity is reduced. Given political realities in Bolivia, this is most likely to be realized through nonmarket distribution of either rangeland or grazing leases at low or zero cost since this will result in improved equity for peasants relative to alternatives.

SOCIAL AND ECONOMIC COSTS OF MODERNIZATION IN HIGH ALTITUDE ANDEAN RANGELANDS.

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This paper analyzes environmental constraints on range management in highland Peru, describes traditional and modern management techniques, and evaluates costs and benefits associated with modernization. Range management in the southern highlands of Peru at elevations above 4000 meters is strongly conditioned by the low temperature, the seasonality and irregularity of rainfall and poor soil quality. Within these constraints, there are two distinct patterns of range management: (1) a traditional type, including Indian communities, undercapitalized ranches and cooperatives, and (2) a modern type, including capital-intensive ranches and cooperatives. Associated with each type are different patterns of land ownership, grazing rights, labor organization, capital

investment, livestock handling and marketing of meat and wool. The modern type has higher levels of productivity per acre and per animal. However, there are strong social and economic costs associated with it. (1) increasing unemployment, (2) depopulation of rural areas and migration to overcrowded cities, (3) decline of cottage industry, (4) decline of agricultural production in adjacent areas, (5) increasingly unbalanced income distribution, and (6) decreased levels of capital formation in rangeland areas. The reasons for these costs are located in the institutional structure of Peruvian society and economy. This paper examines the implication of the modernization of range management in other underdeveloped countries.

ESTIMATING COSTS OF PRODUCING FEEDER CATTLE IN THE UNITED STATES

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A program of research is being carried out by the Economic Research Service, U.S. Department of Agriculture to analyze the structural characteristics and economic aspects of producing feeder cattle and calves. Data from the 1975 Cost of Production Survey conducted with a sample of 1,922 cattle raisers in the U.S. are being used to develop representative cattle raising enterprise budgets.

Recognizing the differences in land resources, types of farming, and cattle enterprises in the U.S., 36 subregions have been delineated and enterprise budgets are being constructed to represent the dominant cattle and forage raising systems in each. Structural characteristics obtained in the survey that appear to have the greatest influence on cost of production include, (1) the cattle raising systems such as the cow-feeder (cow-calf, cow-yearling) and stocker-feeder (2) the herd sizes of each, and (3) the forage system used by each (pasture, range, forage, other crops). An example is developed from subregion SW-4, where the cattle raising systems and forage systems are among the most complex of the various subregions.

Indications are that three cow-feeder enterprise budgets will suffice for representing this enterprise in the subregion SW-4 where 66.7 percent of the operators and 80.7 percent of the cows would be represented; while 73.7 percent of the operators and 87.9 percent of the stockers would be represented by three stocker-feeder enterprise budgets, complexities in the combinations of forage systems used could increase the required number for adequate representation to seven.

Other structural characteristics used in budget determination include number, size, type and value of buildings and improvements, machinery and equipment, along with estimates of allocation to the cattle raising enterprise. Cattle enterprise characteristics such as calving and weaning dates, calving rates, stocker purchase dates and weights, cattle and calf death losses, cattle selling weights, and supplemental feeding practices are also used.

Production costs include direct costs of feed, veterinary services and medicines, marketing, fuel, repairs, hired labor, general farm and ranch overhead, and interest on operating capital. Indirect costs include the ownership costs, consisting of depreciation, interest, taxes and insurance on machinery, equipment, buildings, and livestock. Operator and family labor, and management costs are included as indirect costs,

as are land taxes and interest on land investment. These direct and indirect costs are further divided into cash and noncash costs.

The Farm Enterprise Data System's (FEDS) Livestock Budget Generator is used to compute the budgets once all the required data are derived. The generator can be used to produce estimates of U.S. average unit production costs for feeder cattle and calves, and a variety of estimates of aggregate input use.

AN EVALUATION OF CHANGES IN FORAGE QUALITY AND QUANTITY USING LINEAR PROGRAMMING.

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The management of natural resources is a complex task requiring arts and sciences of many disciplines. The management of federal grazing lands has the added complexity of having ranchers who want to make an economic profit using these grazing resources. One of the problems the federal-land manager has is to determine the value of these grazing lands to the user in terms of both quantity and quality.

The importance of changes in quantity and quality of range forage to permittees on BLM allotments in the San Luis Valley of Colorado was evaluated using linear programming techniques. It was found that benefits to the individual rancher of increasing forage quality and quantity on BLM lands varied with the size of the operation, and percent dependency on government land in supplying the total forage requirements. Data needs for adequately evaluating these changes were identified.

CRITICAL VARIABLE ANALYSIS IN NATURAL RESOURCE PLANNING.

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Because simulation models play an increasingly supporting role as information sources for the natural resource decision making process, we face increasing need to examine the quality of the information linkage at the simulation-optimization model interface. Identification of sensitive parameters and variables can aid research by pinpointing these critical variables as areas of needed research.

A multiple-resource simulation model, TERRA, provides information of resources interactions, ecosystem processes, and harvest ramifications for a mountain watershed located in the Front Range of the Colorado Rocky Mountains. This information is generated through sets of difference equations to represent processes (weather conditions, hydrologic functions, forage production, timber production, and domestic population dynamics, recreation use, and management activities) from the "simulation planning overhead" (updating, plotting, and printing).

Information generated by the simulation is used as input for a linear programming model that is formulated to allocate scarce resources on lands of Arapaho-Roosevelt National Forest while minimizing administrative costs.

Sensitivity analysis or critical variable analysis on both the optimization and simulation models examines the quality of the information between the models. Coefficients for recreation use and harvestable timber are identified as critical elements in the A matrix of the optimization model. This fact coincides with the importance of these resources on the watershed. Extracing this information to the simulation model and evaluating the contribution of variables to the output of harvestable timber indicate that the number of stems and the wood volume per stem in the older age classes of timber are important. Using sensitivity analysis to evaluate parameters of the recreation submodel shows recreation-use periods and carrying capacities of dispersed recreation to be critical parameters.

Examination of component parts and their interactions can contribute to the understanding of a natural resource system. This understanding of the system and its function may, in turn, aid the natural resource manager in his endeavors to make appropriate decisions about natural resource use.

COPLAN: A NEW TOOL FOR RANGE MANAGEMENT.

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Current economic and energy conservation needs force ranchers to utilize all the information available to them to best manage their operations. One option ranchers are able to use is the Soil Conservation District, where they can obtain inventories, such as range sites and condition, stocking rates, and acreages, and then receive opinions from which to select the best means of management. Through the Soil Conservation Districts, the Range Science Department at Colorado State University and the National Science Foundation are providing the rancher with another tool to best evaluate alternatives, enabling him to better manage his ranch. This method which is now offered to Soil Conservation District cooperators is COPLAN. COPLAN, a systems analysis, allows rapid analysis of large quantities of resource data for a number of management alternatives.

Since 1974, the Soil Conservation Districts have been able to involve 40 ranchers in Colorado in COPLAN. An important part of this tool in management is the evaluation of the program. In addition to questionnaires provided to the ranchers in 1976 and 1977, a questionnaire is presently being used to evaluate the aid being given to ranchers through the Soil Conservation Districts and the Soil Conservation Service in resource management systems. The results suggest this tool allows ranchers to have a better understanding of the exact resources available to them, and those alternatives which can improve their operations. This evaluation also indicates a need for accurate information to be supplied to COPLAN, in order to allow the rancher a view of his operation as it is now, and how effective and efficient use can be made of the alternatives.

DECISION THEORY IN THE MANAGEMENT OF RENEWABLE NATURAL RESOURCES.

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The planning and decisionmaking process of individuals involved in management of renewable natural resources has been studied for more than 15 years. Recent studies using simple analysis techniques for developing resource management strategies have provided some insight for a theoretical basis of decisionmaking.

Management strategies can be represented in set theory as sets with a family of non-null sets. Each strategy set, therefore, constitutes a means, acceptable to the decision maker, of achieving the goal. Therefore, the goal is a set formed by the intersection of acceptable strategy sets. Uncontrolled external variables may impose constraints on a chosen strategy set forcing the decision maker to shift from one set to another set in the union of sets.

A good understanding of the relationship between management strategies and the quantifying of as many variables as possible will aid in developing a more implementable management plan.

Section 3. Basic Range Ecology and Rangeland Ecosystems

ALTERNATIVES FOR ECOSYSTEM CLASSIFICATION AND THEIR IMPLICATIONS FOR RANGELAND INVENTORY,

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Three basic approaches have been used around the world to classify rangeland ecosystems. Component classifications use individual factors (e.g. current vegetation, soils) assuming that other aspects of ecosystem and management needs can be related to the chosen factor. Integrated classifications use combinations of two or more factors (e.g. soils and vegetation). Integration is often intuitive and the rules for combining factors rarely quantified. Whereas the first two approaches can be placed independent, regionalization involves a delineation of space on the basis of environmental or biotic affinities. Since generality and specificity can not be maximized at a single chosen level, hierarchical classifications are the usual case. Different factors have natural breaks involving different criteria at different levels. Changes may be naturally continuous in time and space and classifications necessarily arbitrary; however, discrete units are demanded by managers for maps to be drawn and decisions to be made. The strengths and shortcomings of the major ecosystem classification systems being used for rangeland ecosystems around the world will be outlined. This comparison will likely help those updating old or designing new systems to make decisions on what is best for their implementation, given constraints of natural ecosystem variability, the complement of resource values, budgetary adequacy, and educational levels of technicians and users.

PHYTOGEOGRAPHICAL DIVISIONS OF AFRICA.

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The history and development of phytogeography is briefly reviewed. Phytogeography is a branch of botany that has not been widely debated in English. Consequently, some terms and concepts, such as empire or kingdom, sub-kingdom, region, domain, sector or district, and element, are poorly defined. Earlier work by Monod and Troupin on the phytogeographical divisions of the African continent is revised, and proposed divisions are presented in a map showing the regions comprising the Afro-Mediterranean, Saharo-Sindian, Saharo-African, Sudano-Zambezian, Guineo-Congolese, Karroo-Namibian, Afro-Montane, Madagascar, Intertropical Coastal, Cape, and their domains. The corresponding major vegetation types to those regions are discussed.

PLANT DEMOGRAPHY OF AUSTRALIAN ARID RANGELAND AND IMPLICATIONS FOR MANAGEMENT, RESEARCH, AND LAND POLICY.

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Domestic livestock (sheep, cattle, goats, donkeys, camels, horses) and the European rabbit have become naturalized in arid rangelands following settlement by Europeans over the past 180 years. Large populations of the original soft-footed herbivores were unlikely in a land where there were no perennial streams and little surface water. In southern Australia the resulting population explosions of sheep and rabbits culminated in a series of crashes in various regions, starting in the mid-1890's in western New South Wales.

The demography, and particularly the recruitment and survivorship of cohorts, of a small number of perennial grasses, shrubs and small trees suggests that (a) recruitment is episodic and large cohorts are rare (1 in 25, 1 in 50 years), (b) only large cohorts give rise to long-lived populations; (c) the half-life of rangeland plants can range from a few months for grasses to more than 150 years for a shrub species, (d) the sheep and rabbit populations either singly or together can eliminate juvenile recruits which vanish without trace, and (e) a number of desirable perennial shrubs are now represented in some rangelands only by sparse geriatric populations whose origins predate the introduction of the exotic herbivores.

The continued depredations of sheep and rabbits in southern Australian rangelands are likely to eliminate certain plant species that enable the breeding flocks to bridge the long rainless periods, this in turn will threaten the economic viability of pastoral enterprises.

The time scale over which rational management, research and legislative programs will need to operate in ecological systems of the type described here are very long and could easily encompass 5 or more changes in land ownership, 10 or more changes in research personnel, and 30 elections at State and Federal Level.

In these circumstances, forestry timescales appear to be a better model for action than the usual annual cropping-sown pasture timescale.

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ZONATION OF HERBACEOUS VEGETATION ASSOCIATED WITH HONEY MESQUITE IN NORTHCENTRAL TEXAS

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Herbaceous vegetation often occurs in zones about honey mesquite plants growing on the deep hardland range sites in northcentral Texas. The vegetation develops in response to protection from intense grazing provided by the mesquite. The response results from modifications in the microclimate beneath the canopy. Species composition of the vegetation zones greatly influence the rate and direction of secondary succession following brush control.

Three vegetation zones were observed to occur about individual honey mesquite plants. Vegetation occupying these zones were sampled for species frequency, composition by weight, and herbage production following brush control treatments. The brush control treatments included in the study provided an array of ecological disturbances. The treatments included foliar applications of herbicides, mechanical control by tree grubbing and root plowing, and the untreated controls.

Herbaceous vegetation directly beneath the canopy was found to consist primarily of cool season species. Warm season species were often present in this zone prior to brush control treatment but only in minor proportions. Sparse vegetation, consisting primarily of warm season species, occupies an area that extends from the drip line out several feet beyond the honey mesquite canopy. The third vegetation zone forms the interstice between the honey mesquite plants and consists primarily of warm season snotgrass species.

The zonal vegetation is released by brush control treatment. The most rapid changes appear to come from extant warm season species in the canopy zone. The initial effect includes changes in species composition and increased production in the zone of sparse vegetation surrounding the honey mesquite plants. Following brush control, rangeland improvement is influenced by the rate and direction of succession from the zonal vegetation. The importance of canopy zone vegetation is usually overlooked in managing rangelands following a brush control treatment. These results indicate that rangeland improvement can be accentuated by considering the choice of brush control, level of grazing management and season of use on zonal vegetation.

ECOLOGY OF RANGE COMMUNITIES IN NORTH WESTERN LIBYA

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Quantitative description and ecology investigations of semi-arid rangelands in northwestern Libya were initiated in May, 1976. A 25,000 ha livestock enclosure near Assa, some 25 km from the Mediterranean seacoast, was utilized. Average annual precipitation is 120 mm, most occurring from October to March. Average temperature is about 35 C. Soils are mostly azonal sands with pH values from 7.5 to 9.0. The water table, as shallow as 135 cm beneath the surface, was

usually saline, indicating possible sea water intrusion. Average elevation was about 5 m. Vegetation and soil relationships were investigated with permanently established transects for measures of plant cover and density, and by soil profile sampling for detailed analysis of physical and chemical characteristics. Stable rangeland sites were characterized by four communities. The *Artemisia campestris* community was the most common. The *Thymelaea microphylla* type was a common on slightly saline areas, while the *Suaeda vermiculata* community occurred on the most saline sites. *Lygeum spartum* formed a perennial grass community of importance. The dune sand and blowout-pavement types were distinguished because of soil conditions. The dune sand type characterized by dominance of *Bassia muricata*, *Aristida pungens* and *Artemisia campestris*. *Stipa nitens*, *Thymelaea microphylla* and *Artemisia campestris* were dominants on the blowout-pavement areas. Annual grasses were common understory components of stable rangeland, but not on the disturbed soil sites.

MONITORING THE KALAHARI DESERT

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There has been talk of the desertification of Southern Africa for some time and there is localised evidence to the effect that grazing lands are deteriorating. The object of the work reported here is to investigate the trend and condition of the rangelands in Botswana. Twenty permanent transect and quadrat sites were established in 1973 covering the various ecological zones of the country. Factors such as basal cover, frequency, and density of species have been recorded annually for both the lower layer of herbs and grasses, and the upper layer of trees and bushes. Five computer programmes have been developed for the comparison of sites and years.

BUSH ENCROACHMENT ON THE RHODESIAN HIGHVELD

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The spread and establishment of the commonest tree species into cleared grass pastures of the Rhodesian highveld was studied between 1961 and 1965. It was found that seed dispersal mechanisms were inefficient; that the microenvironment for germinants was so unfavourable as to inhibit establishment; and that soil moisture stresses were inimical to survival of seedlings through their first dry season. Control of bush encroachment under these conditions was thus directed to thorough initial cultivation and removal of tree roots when pastures were being established.

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WESTERN JUNIPER COMMUNITIES ON RANGELANDS OF THE PACIFIC NORTHWEST.

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Western Juniper (*Juniperus occidentalis* var. *occidentalis*) is considered to be the northwest representative of the intermountain pinyon-juniper woodland. Conflicting objectives in management of juniper lands has become a major concern. Hence, demands have increased for information about juniper communities and their relationship to adjacent vegetation. A broad picture of western juniper communities is presented, primarily from literature. Vegetation-soil-site information is summarized for central and eastern Oregon, northwestern California, and southwestern Idaho.

Natural fire cycles apparently limited the distribution of the species. However, in the absence of fire, effective moisture appears to determine distribution. Fire suppression and reduction of ground fuels through heavy grazing have allowed juniper areas to increase. Heavy grazing probably also contributes to increased stand density. Where juniper expands into shrub-bunchgrass communities, it commonly dominates the site. Individual trees alter the understory composition and affect soil properties under their crowns. These influences, including residual effects after juniper removal, must be recognized when judging effectiveness of management practices. Controlled burning of juniper-dominated ranges may be an effective way to diversify habitats and increase forage.

ARIZONA FESCUE MOUNTAIN RANGELANDS.

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The Arizona fescue (*Festuca arizonica*) mountain rangelands are primarily forested lands commonly known as ponderosa pine (*Pinus ponderosa*)-bunchgrass ranges. Their distribution is found within the states of Arizona, Colorado, and New Mexico, U.S.A.

Herbage production varies from about 1,200 kg per ha on moderately grazed open grasslands to about 70 kg or less under dense timber. The crude protein and digestibility of forages grown in the open are higher than forages grown under a timber overstory. The nutritional value of the typical summer range diet is generally adequate for cattle, but crude protein may drop below required levels by late September.

Domestic livestock make up 88 percent of the animal biomass while the remainder is contributed by a variety of wildlife species. Seasonal production of beef varies from about 36 kg per ha in openings to near zero under dense ponderosa pine stands.

Present and future demands on these forested rangelands in addition to grazing include timber production, wildlife habitat, and rapidly expanding recreational pressures.

MODELING PLANT SUCCESSION IN ASPEN ECOSYSTEMS.

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Quaking aspen (*Populus tremuloides* Michx.) occupies approximately 2.5 million ha of federal and state-owned land in the Central Rocky Mountain Region of North America. The importance of the aspen ecosystem as multiple-use rangeland is shown by the variety of resources it provides, i.e., forage for domestic livestock, wood fiber, water, wildlife forage and habitat, recreation, and aesthetic values.

We are attempting to develop a comprehensive understanding of the attributes and functioning of the aspen ecosystem to provide a biologically sound basis for evaluating resource and management alternatives.

A generalized dynamic model of aspen succession, developed to analyze the functioning of the ecosystem, is being modified to be more site specific. The ultimate goal is to produce a comprehensive model that describes the aspen system and its response to management activities. This model then can be used by land managers as an additional tool for management decisions.

Sensitivity analyses are being conducted on the model to determine its validity and to identify needs for additional data. The model will be modified and parameters added to make it site specific.

THE RANGELAND OF THE AFRICAN SAHEL: RANGE TYPES, DYNAMICS, PRODUCTIVITY, AND DEVELOPMENT OUTLOOK.

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This paper reviews some forty range surveys and ranch operations carried out over the past twenty years in the Sahelian zones of Mauritania, Senegal, Mali, Upper Volta, Niger, Nigeria, Chad, and Sudan. The surveys covered close to one million square kilometers, which is about one third of the Sahel acreage.

After a short ecological description of climate, soils, animals, people, and management practices, the paper describes main range types. Factors influencing range dynamics, including development schemes, are identified. Both primary and secondary production, as well as the factors affecting the quality and quantity of production, are assessed. Some major constraints to range improvement are examined; and possible development strategies are discussed.

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RECORD DROUGHT ON CALIFORNIA'S ANNUAL GRASS RANGELAND.

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The 1976-77 California record drought decreased range forage production 50-75 percent, caused livestock numbers to be reduced by 15-25 percent and resulted in over \$500,000,000 loss to the livestock industry. The greatest impact was to cow-calf and stocker operations. Heavy culling of cows and replacement heifers took place when prices dropped back to 1972 equivalents. Some stockmen were required to feed hay at 4.5 - 6 kg/day/cow for 6-18 months and hay costs soared to over \$110/t. Weight gains for weaning calves were reported down 45 kg of normal. Stocker operations were devastated by the short green feed period and weight gains were down 45-68 kg from normal. Some cows lost 69-100 kg of body weight which left them in poor breeding condition. Many classes of livestock were placed in feedlots, and the death loss jumped as high as 4 percent. 1976-77 annual precipitation was 30-60 percent of normal and ineffective erratic moisture patterns caused many annual forage species to germinate and die 4-6 times. Range forage was nearly gone and below normal accumulations of residue and litter were widespread over 9,000,000 ha of annual grass rangeland. Evaluations of total organic residue in the O horizon was found to vary from a low of 784 kg/ha on some heavily grazed units to 9,736 kg/ha on some lightly grazed units. Growth chamber tests indicated that on most range units an adequate number of seed for ground cover and forage still existed after the drought's impact, however a shift in forage species composition was anticipated. Total seed numbers were found to be related to the amounts of residue and seeds were found to vary from 10,495/m² on the lightly grazed units, to 22/m² on the heavily grazed steep slopes. Stockmen combined their efforts with state and federal agencies to counteract the drought's impact by range seeding, fertilization, water development and fencing.

PLANT BIOMASS AND NUTRIENT CYCLING ON A GRAZED, TALLGRASS-PRAIRIE WATERSHED.

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A 60-hectare, tallgrass-prairie watershed in northcentral Oklahoma with measured cattle grazing pressure has been intensively sampled from April, 1976 to present for: N, P, Ca, and K in the soil A horizon; live, standing, dead, and ground litter vegetation; cattle dung and urine; and runoff water. The soil, vegetation and dung from 29 permanent locations on eight different soil types were collected and analyzed monthly. Live vegetation, species composition and production, and soil profile water content were also determined at least monthly at all locations. Because of drought conditions, live and standing dead biomass peaked in June, but ground litter biomass (including dung) remained relatively constant over all growing season, sampling periods. Nitrogen, phosphorus, and potassium contents in live

vegetation declined rapidly from April to June and remained relatively constant between June and dormancy in mid October. Relationships between nutrients in live and standing dead vegetation, ground litter, dung, and soil were affected by soil fertility, stage of plant maturity, dominant plant species, precipitation, and several other measured factors. The overall significance of this study is the range of values for the large number of parameters measured and samples collected and the derivation of basic, rangeland nutrient cycling models.

HERBAGE BIOMASS CHANGES ON SOME INDIAN RANGELANDS.

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This paper reports the herbage biomass changes of some semiarid Indian rangelands situated on varying topography. The green vegetation starts growing after the first shower of rains in June, reaches peak growth during August-September, and declines to relatively low biomass during summer season. The root material shows bimodal growth pattern, the first and the second occurring in monsoon and winter season, respectively. The analysis of variance on various standing crop categories shows significant time effect. The extent of variation accounted for and the variables grouped in each principal component on site at hill top differs with the corresponding principal component on sites at hill slope and hill foot. The underlying biological factors for such differences are described and quantified.

PRIMARY PRODUCTION OF TRANSITIONAL MEDITERRANEAN STEPPE.

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The primary production of Mediterranean steppes was studied under various grazing and clipping treatments. The undisturbed primary production was fairly stable from year to year in spite of wide climatic fluctuations, especially in the amount and distribution of precipitation.

This stability is apparently due to the fact that the amount of rainfall was appropriate in all the years so that only a fraction of the rainfall was utilized by the plants.

Only the rainfall distribution has a measurable influence on the primary production.

The influence of various environmental factors on the primary production was analysed by means of various logistic growth models. The relative growth rate was considered as a product of maximum relative growth rate and sigmoid reduction factors representing various environmental variables. The model with the best fit to the data contains reduction factors due to radiation and soil moisture. When the parameter temperature was added, the fit to the measured growth curves was not improved.

The form of reduction factors approached that of a step function. The primary production of the steppe did not decrease as a result of grazing during ten consecutive years.

During this period up to 80 percent of the annual biomass produced was removed during each grazing season, which extended from January to September. The negligible effect of grazing on primary production was apparently due to the fact that during the growing season the growth rate of the vegetation was higher than the consumption rate of the animals. Also, as the grazing season included from four to five months of summer grazing, more than 40 percent of the biomass was removed when the plants were dormant or dead. The amount of dry biomass left on the range at the end of the summer had little or no influence on the primary production during the following season.

The primary production under rotational grazing treatment was a little higher than that under continuous grazing. The difference between these two methods was significant only when the biomass at the beginning of the season was relatively small and when the comparison was done under conditions of heavy grazing.

Herbage removal by clipping reduced the total primary production in direct relation to the number of clips.

ABOVE GROUND ANNUAL DRY MATTER DYNAMICS OF THE GRASS LAYER IN A TREE SAVANNA ECOSYSTEM.

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A Savanna Ecosystem Research Project was launched in South Africa in 1974 on a veld type called the *Eragrostis pallens*-*Burkea* Tree Savanna, receiving about 600 mm summer rainfall per annum. The veld type is one of several occurring in the Nylsvley Nature Reserve, near Naboomspruit, Central Transvaal.

Peak biomass in the open subhabitat varied between 62.3 and 103.3 g/m² between 17 December and 10 February. A double Compertz mathematical function plus a constant gave reasonably good fitting curves for biomass production over a year. Biomass accumulation rate curves were derived from these. Biomass in the open was 44 percent higher than under trees, but with an open/canopied surface area ratio of 72.5:27.5 was only 5.65 percent higher than in the combined subhabitat. Equivalent figures for standing crop were: 70 and 10.44 percent, respectively. Peak standing crop in the open varied between 181.4 and 235.4 g/m² between 7 December and 13 April. Biomass as a percentage of standing crop (unburnt but grazed) was highest, 40 to 55, between January and April. Combined subhabitat stubble mass varied mainly between 200 and 300; grass and tree litter between 200 and 500; and grass litter between 50 and 85 g/m².

This type of study has practical implications in assessing and predicting the animal production potential of a veld type; and, the effect of different managerial practices like grazing, burning and de-treeing on biomass production and nutritive value of the grass layer. From the ranching point of view, studies on the preferred species group of plants and the effect of de-treeing are particularly important.

PLANT SUCCESSION IN SOTUBA GRAZING LAND.

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The survey of plant succession of the native grazing lands of Sotuba has shown that the vegetation has undergone successive changes since all agricultural activities ceased in 1930. Plant succession has been extremely slow on laterite soils of Piedmont, slow on the remodeled sandy formations, relatively rapid on well developed soils of the alluvial plain, and extremely rapid on the soils that are inundated annually by runoff water.

Plant succession has been thwarted by the combined action of agriculture, bush fires, utilisation as pasture, and the control of invading species.

TEMPORAL SEGREGATION IN SOUTHERN CALIFORNIA ANNUAL GRASSLAND.

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Annual grasslands characteristically experience a succession of seasonal phases which provide for the coexistence of various species by allowing them to make their major demands upon environmental resources at different times. Thus, an ecosystem furnishing certain resources at a limited rate is enabled to support a larger total biomass.

The grasslands of Southern California consist principally of annual grasses coexisting with the few remaining native perennial grasses. Characteristic also is the inclusion of forbs which are distinctly either early spring or late summer plants. Many spring forbs, annual grasses and summer forbs are observed to germinate in approximate unison shortly after the first winter rains. In spring, however, differing individual responses to environmental opportunities and stresses segregate these species along a time gradient. The effect is that the grassland then passes successively through a spring phase dominated by filaree (*Erodium* spp., Geraniaceae), an intermediate phase dominated by annual grasses (e.g. *Avena* sp., Poaceae) and a summer phase characterized by tarweed (*Holocarpha* sp., Asteraceae).

To determine the value of specific environmental factors in segregating annual grassland plants along a time gradient, representative species were studied in field and controlled-environment conditions. Growth of the plant species in field plots was observed over a three-year period, and the individual and collective patterns characterized and quantitatively described. Climatic and microenvironmental factors were simultaneously monitored and then correlated with plant growth. Effects of intra- and inter-specific competition were examined by sowing all possible combinations of the three species into sterilized soil of field plots, each combination repeated in three different densities. Effects of temperature, daylength and soil moisture tension were determined by growing the species in controlled environments.

Correlation of field development with environmental conditions served only to suggest hypotheses for experimental testing. Competition, while affecting individual species development, is not significantly important in phase segregation. Filaree,

slender wild oat and tarweed are segregated along a temporal gradient by their differing individual responses to particular combinations of temperature, daylength and soil moisture tension.

PRODUCTIVITY OF LOLIUM RIGIDUM IN A FOREST OF OAK TREES (QUERCUS SUBER).

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The main objectives of the experimentation held during 1973, 1974 and 1975, in 3 different ecological sites, were to study the productivity of Lolium rigidum for improving the forestry range lands and determine if Lolium rigidum could grow under different densities of Quercus suber. The following results for three years experimentation have been obtained: (a) Lolium rigidum prefers clay soil; (b) Lolium rigidum grows in sandy soil only under Quercus suber, (c) Nitrogen has significant effects on the yield of Lolium rigidum; (d) The growth of Lolium rigidum in the forest is more vigorous than Lolium rigidum outside the forest; (e) The yield of green matter and dry matter increases correlatively with the densities of Quercus suber.

COMPARISONS OF WINTER AND SPRING PRESCRIBED FIRES ON LOUISIANA PINE-BLUESTEM RANGE.

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The cutover longleaf pine (Pinus palustris Mill.) land of the southeastern United States, which were maintained as virtual bluestem prairie by annual wildfires for the first half of this century, have been almost completely restored to pines. Fire, although now carefully controlled, is used to prevent the build-up of litter which is a wildfire hazard and is also detrimental to forage production. Most prescribed burning is done in midwinter; however, a recent study indicated that May fires are beneficial to the growth of longleaf pine seedlings. In a similar study in a young slash pine (Pinus elliotii Engelm.) plantation in coastal Louisiana, the effects of March and May fires at 1-, 2-, and 3-year intervals are being compared. Burning began when trees were 5 years old and averaged 2.4 m tall.

After seven years of treatments, survival and height growth of trees on burned plots did not differ significantly from those of unburned plots. Herbage yields on plots burned in March were greater than those on unburned plots or plots burned in May. Botanical composition of herbage was affected more by frequency of burn than by season of burn.

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FIRE-A RANGELAND TOOL IN SOUTHERN AFRICA.

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Results from burning experiments conducted over the last 57 years have led to the development of fire as a practical and economic tool for rangeland management and improvement in Southern Africa. Burning is used to maintain grassland in a vigorous and acceptable state for ungulates and for controlling the encroachment of woody vegetation. Studies are described where in the Eastern Cape Province controlled burning and deferment programs have been developed to eradicate macchia vegetation and Helichrysum species. Furthermore, experimental results are presented where the intensities of fires have been studied in relation to environmental variables and correlated with the effect on the vegetation. This data has been successfully used to reduce the level of browse material of Acacia karroo to an available height for goats by destroying the stems and branches of 72 percent of the trees and causing coppice growth to develop at the base of the plant. Subsequent continuous stocking with goats has resulted in 80 percent of the trees being killed. The application of these principles of plant and fire ecology provides a solution to many of the extensive bush encroachment problems of Southern Africa and also possibly to similarly affected areas in the United States of America and Australia.

EFFECTS OF BURNING, CATTLE GRAZING, AND TOPOGRAPHY ON VEGETATION OF THE CHOPPY SANDS RANGE SITES IN THE NEBRASKA SANDHILLS PRAIRIE.

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Burning, grazing, and topographic location, factors important to understanding grassland community dynamics, were evaluated on the Choppy Sands range site of the Nebraska Sandhills Prairie. Vegetative cover averaged 70 percent and biomass 223 g/m² on ungrazed and unburned areas. North-facing slopes of hills were dominated by needle-and-thread (Stipa comata) (37 percent coverage), south-facing slopes by prairie sandreed (Calamovilfa longifolia) (27 percent), and hilltops by both species (20 percent and 22 percent respectively). Depressions between the surrounding hills were dominated by sunflower (Helianthus spp.) (16 percent) and by annual grasses, primarily cheat grass (Bromus tectorum) (9 percent) and six-weeks fescue (Festuca octoflora) (6 percent). Vegetative regrowth was reduced 26 percent one growing season after burning although burned areas averaged only 8 percent less cover after two growing seasons. Cover of sandhill muhly (Muhlenbergia pungens) was consistently reduced by burning. Needle-and-thread and prairie sandreed were also affected by burning although the results differed with topographic location. Vegetative cover and biomass on moderately grazed sites was 14 percent less than on ungrazed sites. Sandhill muhly increased 8 percent under grazing but needle-and-thread, yucca (Yucca glauca), sand dropseed (Opobolus cryptandrus), and sand bluestem (Andropogon hallii) consistently declined. Vegetative cover and composition appear to be variously affected by different combinations of burning, cattle grazing, and to-

pographic location although further research is essential to more fully understand the extent of the interrelationships.

LEAFY SPURGE (*EUPHORBIA ESULA* L.) CONTROL BASED ON A POPULATION MODEL.

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A pictorial model of the life cycle of leafy spurge was constructed from experimental data collected from a population that was undisturbed and from one that was treated with a herbicide. The model included two main methods of reproduction: seed (sexual subsystem) and vegetative buds on roots (vegetative subsystem).

In the undisturbed population, 99 percent of the roots were produced by the vegetative subsystem. When picloram was used as a perturbation, there was a disruption in the homeostasis of the system and the sexual subsystem became the major operating part of the model. In Saskatchewan, picloram gave control of the vegetative subsystem for 3 to 5 years. During this time, 130-1620 seedlings/m²/year appeared in the spring and died by fall. Once the herbicide residue disappeared, seedlings survived and the sexual subsystem was responsible for reestablishing spurge in the area. At least seven years, without the input of fresh seeds, were required to reduce the soil seed bank from 8,000 to 5 viable seeds/m².

The model suggested that the first application of picloram controlled vegetative reproduction and that a retreatment was necessary to reduce the soil seed bank in order to prevent reestablishment by seed. The effect of other herbicides for leafy spurge control can easily be predicted using this dynamic model.

AFFORESTATION FOR SAND DUNE STABILIZATION IN AL HASSA OASIS, SAUDI ARABIA.

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Al Hassa Oasis in eastern Saudi Arabia, the largest and most important irrigated agricultural area in the country, was being covered by moving sand dunes. A large scale sand control project was started in 1962 using afforestation with irrigation. *Tamarix aphylla*, *T. gallica*, *Acacia cyanophylla*, *Parkinsonia aculata*, *Prosopis juliflora* and *Eucalyptus camaldulensis* were used. Only *Tamarix aphylla*, *Prosopis*, and *Acacia* have grown successfully. *Tamarix aphylla* has shown the best survival and height growth, averaging up to 5,900 stems per ha and 7.2 m in height at age ten years. In 1975, plantings of *Tamarix* cuttings 100 to 120 cm long were made without irrigation. At eight months of age, survival ranged from 99 percent and height 2.1 m with a sand depth of 50 cm, to 50 percent and 0.3 m where the sand was 200 cm deep.

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VEGETATIONAL DIFFERENCES ON NATIVE RANGE DURING 38 YEARS IN EASTERN MONTANA.

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Vegetation was charted on 19 permanently located plots (30 by 152 cm) on five sites near Mildred, Montana, in 1938 (2 years after a severe drought), in 1963 (2 years after another severe drought), and in 1976 (15 years after a severe drought). The 1960's drought was not as severe as the 1930's drought. The frequency of occurrence of two of the four major species increased on only two or three of the five sites. During the moist period after the 1960's drought, western wheatgrass (*Agropyron smithii*), threadleaf sedge (*Carex filifolia*), and needleandthread (*Stipa comata*) increased on all sites, but they increased on some more than on others. Needleandthread and prairie junegrass (*Koeleria cristata*) seemed to be the least drought tolerant species, whereas blue grama (*Bouteloua gracilis*) and threadleaf sedge seemed to be the most drought tolerant.

NATURAL AREA NEEDS FOR RANGE RESEARCH.

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Range research should include the natural ecosystem as part of the experimental design much more than in the past. We need to study natural ecosystems and compare them with domestic-animal-grazed systems to gain research objectives and detect unintended effects much earlier than without such comparisons. Where natural ecosystem research areas are not available, they should be promptly established because suitable sites continually decline. Fortunately, support for natural area preservation and research is increasing rapidly.

A CRITICAL EVALUATION OF THE RANGE CONDITION CONCEPT.

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The concept of range condition is one of the most important in range management and has been widely used for determining management effectiveness. Two general approaches have been used: (1) a climax approach in which present vegetation is measured against pristine or climax condition and (2) a site-potential approach in which present forage production is measured against potential for the site.

The climax approach has been most widely accepted but is criticised because: (1) the climax is not usually an attainable or desirable goal for management, leaving the range manager in a position of having to justify why he manages for less than "excel-

lent" condition, (2) pristine conditions are not necessarily the present climax, (3) reseeded ranges or naturalized exotics are not easily accommodated, and (4) it is not well suited to forest or woodland rangelands. The site-potential approach results in a different condition rating for each use, no one of which is readily interpretable in terms of site stability.

It is proposed that the concept of range condition be modified to include two separate ratings (1) a measure of site condition based on soil characteristics and (2) a use rating to measure desirability of present vegetative cover relative to potential for any particular land use.

ENDEMISM IN MEXICAN GRASSES.

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The relatively rich Mexican grass flora consists of about 1,500 species, nearly one-fourth of these species are endemic. Many of them are endangered rangeland plant species.

The identification of endemics and the mapping of their distribution is an important step toward the delineation of biomes and ecosystems in Mexico. All the geographically distinct areas of Mexico have their share of unique species, although the pine savanna is the richest. Relative degrees of endemics are presented for (a) the Sonoran and Chihuahuan deserts, (b) the grasslands of the central plateau, (c) the pine forests, (d) the central mountains, (e) the coastal plains, (f) the coastal salt marshes, (g) the tropical forest margin, (h) the tropical forest, (i) Pacific islands, and (j) gypsum soils.

The age, origin and distribution of these endemics is discussed in relation to the origin of the Mexican flora as a whole.

AN ECOSYSTEM MODEL OF NOMADIC PASTORAL LAND USE.

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An ecosystem model of nomadic pastoral land-use is proposed, based on an African steppe camel, sheep and goat type of economy. The model has three components: (a) energy flow through the system, from fixation of sunlight by photosynthesis into plant material, and conversion by domestic animals into

products for human use; the direction and size of energy flow and conversion efficiencies at each trophic level are the important variables; (b) an energy input-output analysis of the operation of a domestic herd, comparing labour inputs (watering, milking, supervision etc.) with energy outputs (mainly milk); (c) a comparison of the terms of trade (in both energy and cash) of pastoral products traded across the ecosystem boundary for essential non-pastoral products (especially grain and cloth).

Such models may help understand the present situation and plan the future of African pastoralists. Such a model provides a single framework within which information from ecology, economics and history can be brought together to explore the central economic processes of a pastoral society.

PREDATION ON RANGE SHEEP AS RELATED TO PREDATOR CONTROL AND SHEEP MANAGEMENT.

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Range sheep herded in mountain grasslands on three summer range areas in Nevada and one in eastern California were studied to verify the extent of losses due to predation. Predators were being controlled on Nevada ranges and no control program existed on the California site.

Control consisted primarily of trapping coyotes (*Canis latrans*), but a few were shot with rifles. Only one of the 75 coyotes killed in the control efforts was shot using aerial gunning. On one summer range 43 coyotes were removed, 30 on another, and 26 on the third.

The losses of lambs from the four bands of sheep where predator control existed were 4.7, 3.3, 1.9, and 1.5 percent. On the range with no control, 6.3 percent of the lambs were killed by predators. The coyote accounted for 92 percent of total predation.

Sheep management directly influenced the degree of predation. When sheep were permitted to bed in scattered groups, predation was greater. Herders camping in tents adjacent to or near the bed grounds of sheep were a deterrent to predators. Moving sheep from an area where kills were frequent also reduced predation. Fires, flashing lights and exploding devices placed around sheep at night may be effective under some conditions.

Section 4. Rangeland Soils

RELATIONS BETWEEN HEAVY GRAZING, CULTIVATION, SOIL EROSION AND SEDIMENTATION IN THE SEMIARID PARTS OF CENTRAL TANZANIA.

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The paper describes recent quantitative research on land degradation in the Dodoma District, Tanzania. Special reference is made to soil erosion and sedimentation and their relations to land use. Types, rate and extent of erosion as well as the primary and secondary causes of the processes are considered. Sources of sediment are overgrazed areas and cultivations on inselberg pediment slopes. Eroded material "floods" valley floors or is transported by streams to water reservoirs where it is trapped. On the basis of sediment surveys, reservoir lives are predicted. The economic life-length of four reservoirs studied is estimated at between 25 and 100 years. Annual sediment yield per km² amounted to 200-600 m³. Comparisons are made with investigations in similar environments in N. Tanzania and in Kenya.

The development of land degradation in the Dodoma area is partly blamed on uncontrolled extension of cultivations and growing numbers of cattle in conjunction with locally increased population pressure. The present villagization programme in Tanzania implies large concentrations of population and stock at sometimes randomly chosen locations. This may mean further acceleration of land degradation around villages.

A PRELIMINARY APPROACH TOWARDS HYDROLOGIC MODELING OF RANGELAND GRAZING MANAGEMENT SYSTEMS.

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The hydrologic reactions to grazing systems have been modeled and may be used as a guide in the management of wildlands. Specifically, the terminal infiltration rates associated with various intensities of grazing and their time-dependent recovery rates are synthesized into a scheme of reactions, utilizing the best state-of-the-art knowledge and reasonable assumptions. Depending upon available local information and professional judgement, the model may be augmented to incorporate processes of specific site importance and/or operated with stochastic inputs. The model background, application, elaboration and examples of application to management decision making are given.

WINTER RUNOFF AND SOIL WATER STORAGE AS AFFECTED BY RANGE CONDITION.

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These data cover seven winters from a range hydrology study conducted on Mixed Prairie of the northern Great Plains at Cottonwood, South Dakota. Watersheds in high range condition with the most vegetation and mulch captured the most blowing snow and stored the most soil water. However, winter runoff was about the same from watersheds in medium and low range condition as it was from watersheds in high range condition.

HYDROLOGIC IMPACTS OF GRAZING SYSTEMS.

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Hydrologic impacts of grazing systems on rangeland have been of concern in Texas and the western United States for many years. The primary objective of grazing systems is to improve vegetation composition and production, and consequently increase livestock and wildlife production. In many areas these systems are partly justified as mechanisms to improve watershed conditions. Unfortunately, researchers have given little attention to the hydrologic impacts of grazing systems. Previous infiltration and sediment production studies have been conducted by sundry methods on continuously grazed pastures with varying stocking rates.

The status of research knowledge on the hydrologic impacts of grazing systems will be reviewed. Likewise, the results of research in Texas at the Sonora and Throckmorton Field Stations will be presented. The purpose of this research is to measure infiltration rates and sediment production of selected range sites that are subjected to: (1) deferred-rotation, (2) short-duration, (3) continuous grazing, or (4) continuous rest.

Infiltration rates in deferred-rotation pastures were similar to those in an ungrazed enclosure and significantly higher than in continuously grazed pastures. High infiltration rates were attributed to low bulk densities and high mulch cover. Pastures with grazing systems had similar rates of sediment production as pastures rested continuously and sig-

nificantly lower than continuously grazed pastures although the magnitude of difference was not as high as the infiltration rates. Low sediment production was attributed to more standing biomass (live and dead), mulch and increased soil depth. Where grazing systems have improved vegetation cover and soil properties, there is generally an improvement of hydrologic properties of the watershed as compared to continuously grazed pastures.

WATER HARVESTING: AN AID TO RANGE MANAGEMENT

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Thousands of hectares of western rangeland are inefficiently used, because of poorly spaced or inadequate water supplies. Water harvesting could provide the needed water supplies, and thus better management alternatives, for many of these areas.

Water harvesting has been an important way to supplement water supplies for years in northwestern Arizona. It is the only feasible method for supplying water to livestock in much of this area, because perennial streams and springs are rare and groundwater is deep or consists of isolated perched water aquifers. Installation of an adequate grid of watering spots through pipelines and hauling is expensive because of the great distances between existing reliable supplies.

Two water harvesting systems, with paraffin wax catchment aprons, were installed on the Arizona Strip in September 1974, at costs substantially below those where common construction materials like concrete, rubber, and sheet metal have been used. This paper reports the materials used, the costs of the total systems, the economics after two years of operation, and the management alternatives provided.

RANGELAND FORAGE REHABILITATION BY WATER HARVESTING

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Soil moisture and plant nutrients are two major factors that limit forage productivity in the arid and semiarid regions of the United States. By using water harvesting--runoff farming techniques--we increased forage yields of blue panicgrass (*Panicum antidotale* Retz) three to fivefold. Analyses of nitrogen balance within the test plots indicated that the grass is efficient in the use of nitrogen and may actually be fixing some nitrogen. The ability of the blue panicgrass to produce high forage yields without encountering nitrogen deficiencies could be a major step in maintaining production on rangelands.

EFFECTS OF SURFACE-SOIL MORPHOLOGY ON IMPROVEMENT AND MANAGEMENT OF ARID AND SEMIARID RANGELANDS.

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Seven kinds of surface-soils were described on study sites in northern and southern Nevada. These surfaces are related to microtopographic position and have different polygon physiognomy and soil morphology.

Vesicular crusts occur in the dune interspace position between shrubs. These crusts have lower organic matter, higher bulk density, and higher modulus of rupture, than do the coppice-dune soils beneath shrubs. Disturbance of interspace soil by plowing, furrowing, or trampling decreased seedling emergence because these silty soils slake when wet and form a massive crust when dry.

Revegetation through grazing management is theorized to require livestock trampling to plant seed. However, greenhouse and field studies show that seed placed in a dust mulch of an interspace soil did not emerge. Therefore, success of seedling establishment may depend on untrampled "safe sites" in polygon cracks of surface-soil types.

Disturbance of coppice and interspace soils by off-road-vehicle traffic decreased infiltration and increased sediment production after simulated precipitation. Infiltration was 2 to 10 times greater on coppice soil than on interspace soil. The greatest amount of runoff and sediment came from interspace soil after disturbance, wetting, drying, and crust reformation.

HARDPANS IN WESTERN NEW SOUTH WALES, AUSTRALIA.

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Hardpans cemented by silica (duripans) occur extensively in soils of arid Australia. A trench two metres deep recently dug across New South Wales exposed a discontinuous hardpan, not previously known, along a section of 100 km near White Cliffs. Forty-two of the fifty-five representative soil profiles examined contained hardpans. Hardpans were associated with silicified Tertiary laterites, and silica released from dissection of these laterites may be an important source of hardpan cement. The presence of and depth to hardpans are shown to be related to soil type, especially surface drainage and topographic position. Where there is excessive surface drainage, hardpans are at shallow depths but where there is gilgai microrelief and the surface drainage is impeded, hardpans disappear. Bladder saltbush (*Atriplex vesicaria*) and mitchell grass (*Astrebala pectinata*) and other valuable browse species are absent where hardpans are close to the surface. Tyne pitting and contour furrowing techniques are currently being used to establish native perennials on these

hardpan soils. Observations suggest that these techniques may eventually modify the underlying hardpan as well as improve soil conditions for the germination and establishment of perennial species.

GYPSUM, RANGE CONDITION, AND INTERACTIONS OF BOUTELOUA CHASEI ON DESERT GRASSLAND FROM SAN LUIS POTOSI.

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The grassland of Bouteloua Chasei has, at San Luis Potosi, approximately an extension of 75,000 ha, and there are some other significant areas in the states of Zacatecas, Coahuila and Nuevo Leon.

During several years, the Instituto de Investigacion de Zonas Deserticas has identified soil characteristics, and noticed that most of the plants are endemic.

The objective of this work was to look for the interrelations of the soil with the dominant species in such a way that successful practices can be developed.

The result of the analysis showed negative correlations between the basal area of the codominant species and the saturation percent of the soil. The different percent of the basal area of the dominant specie and the codominant are related, but this relation is modified according to range condition.

According to the results obtained, it has been possible to visualize some of the overgrazing areas which in appearance do not correspond to the site.

SEASONAL DYNAMICS AND RESPONSES OF RHIZOSPHERE AND RHIZOPLANE MICROORGANISMS ASSOCIATED WITH SEMIARID GRASSLAND PLANTS.

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To evaluate the possible contributions of bacteria, actinomycetes and fungi, as broad groups, in the rhizosphere and rhizoplane zones of plants in a semi-arid grassland, surface soil cores have been taken at two-week intervals. Respiration (CO₂, O₂) dehydrogenase activity in the presence of five substrates (glucose, starch, cellulose, amino acids, proteins), nitrogen fixation activity and viable count estimates of bacteria, actinomycetes and fungi were measured. Also, mycorrhizal and non-mycorrhizal fungal population changes were monitored by microscopic procedures. To evaluate bacterial fungal contributions to mineralization processes in the rhizosphere and rhizoplane, a laboratory-scale labelled substrate mineralization assay was used with selected antibiotics. The data were analyzed using a matrix analysis program for a whole year, and for the spring, summer and fall periods, to determine the degree of relatedness (direct and inverse) in changes between the various parameters. Generally, changes in fungal viable counts in the rhizosphere and

rhizoplane showed correlations with changes in respiration, which were not shown by the bacteria and actinomycetes. The microscopic fungal measurement, in contrast, did show changes related to viable counts for bacteria and actinomycetes. These results suggest that fungal populations in the rhizosphere and rhizoplane may be more sensitive to changes in substrate availability as measured by respiration rate changes (carbon dioxide evolution, oxygen use), than bacteria and actinomycetes. Mineralization studies using whole soil fractions demonstrated turnover times of 1-8 hours for glucose and mixtures of amino acids, while starch and cellulose required 2-40 hours respectively for 5 percent decomposition. During winter these rates were decreased by approximately 25 percent. Studies carried out to date suggest that in spite of the relatively large fungal biomass in the decomposer compartment, the bacteria are responsible for the major part of the mineralization processes occurring in the rhizosphere-rhizoplane zone of this grassland ecosystem.

WATER SPREADING AROUND THE WORLD.

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Successful water spreading projects have been established in Jordan and West Pakistan. These projects have increased forage production up to five tons of dry forage per hect. These are entirely different types of design as required by the different sites. Although water spreading has proved successful in many cases, it has also produced costly failures.

Water spreading should be recognized as an engineering project that must be designed and constructed to handle volumes of water in movement. The basic principle is to concentrate and hold water long enough to store water in the soil and produce a crop of forage. Because site conditions on potential water spreading projects vary significantly, no set of detailed specifications can be worked up for water spreading design and construction. Certain basic principles apply to most water spreading projects. These include the calculations of volume and frequency of water flow that can be diverted to the water spreading area and carried safely through the system.

Design and construction of dikes within the spreading area are critical. These principles apply whether the dikes are constructed by hand labor and baskets; bullocks and wooden scrapers; or large tractors and heavy mechanical equipment. Through specific discussion of these basic principles, it is hoped that range technicians will recognize possible water spreading sites and proceed with proper design and construction around the world.

MOISTURE RELATIONS IN RANGELANDS, WESTERN UNITED STATES.

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New methods to approximate moisture relations that influence occurrence of range vegetation have evolved during two decades of research on public lands of the

western United States. Moisture-retention capabilities of soils can be determined from measurements of moisture contents and related moisture-retention forces. The moisture-retention characteristics of soils can be described in terms of surface available to adsorb water, number of molecular layers of water adsorbed or depleted, and related retention forces. With this information the force exerted by vegetation per unit of water depleted from storage can be determined. Measurement of differences in volume weight of soils with increasing depth facilitates computations of water depths that are stored in and taken from the solum. Void capacities, computed from volume weights, indicate maximum quantities of water stored. The actual size of drainable voids determines the rate of flow. The energy requirements, quantities of water available, and seasonal precipitation patterns have considerable influence on what species of vegetation occur in various range habitats.

WATER INFILTRATION CONTROL ON RANGELANDS: PRINCIPLES AND PRACTICES.

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The rate and route of water infiltration into rangeland soils depends on the two interacting and interrelated soil surface properties microroughness and macroporosity. These two surface conditions control infiltration by regulating the flow of air and water in soil micropore and macropore systems. Where the surface is rough and macroporous, rainwater penetrates the soil rapidly via the relatively short, straight, broad paths of the macropore system, but where the surface is smooth and microporous, water penetrates the soil slowly via the relatively long, narrow, tortuous paths of the micropore system. The rough macroporous surface can usually absorb water about 10 times faster than the smooth microporous surface. Consequently, a rough-open surface will absorb most of the rainwater from a 50-year maximum intensity thunderstorm; whereas a smooth-closed surface will shed most of this water. If rough-open and smooth-closed surfaces are imposed and maintained for several years, the infiltration may approach two orders of magnitude. The rough-open and smooth-closed surface conditions occur naturally and often side by side in rangelands. Grass or litter covered areas exhibit the rough open condition, but the interspersed bare land areas possess the smooth microporous surface. Rangeland management practices should be directed to controlling surface microroughness and macroporosity for better protection and use of soil and water resources in forage production.

EFFECT OF CONTOUR FURROWS ON THE SOIL MOISTURE REGIME OF A HARD ERODED RIDGE AT COBAR NEW SOUTH WALES, AUSTRALIA.

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The ridges of the Cobar Pediplain have been se-

verely eroded and produce only small quantities of pasture, much of which is ephemeral or inedible.

Recent studies have shown that the main reasons these rangelands have not responded to 11 years of enclosure from domestic animals is lack of moisture penetration, and hence an unfavourable soil moisture regime. Untreated areas had moisture tensions less than 15 bars for 20 days and 11 days of a 250-day monitoring period at 5 cm and 10 cm soil depths, respectively; whereas at various positions in and adjacent to contour mouldboard plough furrows, moisture content was above this level for 109 to 179 days at 5 cm depth and 150 to 250 days at 10 cm depth.

Rainfall of 39 mm was required to reduce moisture tension at both depths of the untreated (inter-furrow) soil below 15 bars. The reasons for lack of moisture penetration are low infiltration rates due to high surface bulk density and formation of an algae-covered surface seal. After contour furrowing, prolific natural reseeding gradually occurs in and adjacent to furrow lines. Vegetation has become established up to 2.4 m uphill and 2.8 m downhill from furrow lines, whilst the remainder of the inter-furrow areas is still bare but for a few plants of grey copper burr (Bassia dicantha) after 11 years.

SEDIMENT YIELDS OF RANGELAND WATERSHEDS.

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The rangelands of the Southwestern United States have deteriorated in this century primarily because of climatic pressure and misuse by man. Rangelands have become more exposed and gullied, with brush replacing grass in many areas. The region also experiences intense convective rains with thunderstorms producing over 1/2 of the annual rainfall in many areas. Sparse cover and intense rain combine to produce relatively high sediment yield rates. Five years of sediment yield data from small (less than 260 hectares) watersheds within the 15,000-hectare USDA Walnut Gulch Experimental Rangeland Watershed in Southwestern Arizona are related to watershed size, vegetation and ground cover, channel type, land uses, and rainfall and runoff characteristics associated with the climatic regime. Sediment yields per unit area decrease with increasing drainage area and with increasing grass and gravel cover (erosion pavement). Sediment yields per unit area are as much as 3 times greater for gullied as ungullied watersheds. Both suspended sediment load and bed load are well correlated with peak discharge and runoff volume. Sediment yields are also well correlated with rainfall amount and the USLE rainfall factor (R).

HYDROLOGIC EFFECTS OF RANGELAND RENOVATION.

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There are roughly 41,600,000 ha of arid and semi-arid rangelands in the Southwestern United States with essentially one value to agriculture--livestock grazing. Because of the large areas involved, small increases in productivity through range renovation can mean substantial increases in grazing potential and food production. Effects of range renovations are often qualitative because of scarcity of hydrologic data. Two small (220 and 40 ha) subwatersheds on the 15,000 ha Walnut Gulch Experimental Watershed near Tombstone, Arizona, with good rainfall and runoff records were renovated. In 1965, the 220 ha watershed was ripped with a Jayhawk soil saver every 2-3 m on the contour and a portion seeded with grass the following year. Rainfall was below normal for several years after treatment, and runoff was greatly reduced. In 1971, the 40 ha watershed was contour root plowed to kill all shrubs and seeded with grass the following year. Rainfall-runoff relationships are more difficult to explain for the smaller watershed because of greater disturbances of the surface area, more intense reseeding, a shorter period of record, and greater rainfall variability. Sediment yields have decreased markedly since renovation.

IMPACTING DIFFUSE SALT PRODUCTION FROM RANGELANDS WITHIN THE UPPER COLORADO RIVER BASIN.

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Diffuse salt production from rangelands is a major problem, especially in portions of the western United States. Most of this salt originates from lower elevation rangelands that yield relatively small quantities of water in a somewhat erratic pattern. Water yields from high elevation lands are generally of high quality and are derived primarily from snowmelt.

Diffuse salt from rangelands is the end product of various land and channel processes. This paper briefly describes the main points from a three year study emphasizing land processes and their impact on salt production from selected rangelands within the Price River basin. The relative importance of vegetation, overland flow, and microchannel flow is given in terms of the total annual contribution of salts to the Price River; and the impact of certain range improvement practices on probable salt loading is also briefly examined.

Section 5. Rangeland Plants

COLLECTION AND EVALUATION OF PLANTS FOR ANIMAL PRODUCTION IN KENYA.

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The eastern African region is the centre of origin of many of the world's most economically important pasture species and fodder plants. However, only a small portion of this enormous forage genetic material has been systematically collected and utilized in pasture and rangeland improvement. Some of the valuable pasture species may become extinct due to the expansion of cultivation or as a result of heavy grazing under prolonged drought periods. An FAO/Kenya project financed by Norway was initiated in 1974 to collect important forage grasses and legumes and evaluate their potential production in different ecological zones. In 1977, the programme expanded to include the collection and evaluation of fodder shrubs. Over 120 grass and 40 legume species comprising more than 2,000 ecotypes have been assembled in five living nurseries representing different ecological zones of Kenya. A cold storage for gene bank has been established to preserve the promising forage material. This is the first of its nature in Africa.

RANGE PLANTS FOR CALIFORNIA HIGHWAYS.

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Several grasses and legumes originally developed for rangeland use have proven to be valuable erosion control plants on California highways. In a five-year study with the California Department of Transportation and the Federal Highway Administration, the Soil Conservation Service showed excellent results on eroding roadbanks and slopes with Blando brome (*Bromus mollis*), Luna pubescent wheatgrass (*Agropyron trichophorum*), Rose clover (*Trifolium hirtum*), and Lana vetch (*Vicia dasycarpa*).

About 80 grasses and legumes were tested on 22 sites in the Sierra Nevada and central coastal regions of California. These plants were compared for erosion control, appearance, volume of fuel, persistence and ease of establishment. Planting sites include cut and fill slopes and other construction areas where revegetation and erosion problems occur. On droughty and sandy soils, the best stands were obtained when the seed was placed in the soil. Establishment was usually better with straw mulch than with wood-fiber mulch.

BREEDING NATIVE GRASS SPECIES FOR RANGELAND IMPROVEMENT IN ALBERTA.

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General fitness or adaptation to local climatic conditions is one of the most important criteria to be used in the selection of plant species for rangeland improvement. Native grass species, which are the product of long-term natural selection for adaptation, are generally considered to be the most promising kind of material for the improvement of rangeland grazed by both domesticated and wild herbivores. A genetic and plant breeding project was therefore undertaken to collect, evaluate and utilize the natural genetic variability in the improvement of various native grass species which are of interest to rangeland development in Alberta. A total of 187 accessions representing 37 species included in 16 genera have been studied. The majority of plants collected from the natural environment showed varying degrees of sterility. The results obtained from cytological studies of *Agropyron* species have indicated that most of the sterility observed was due to natural hybridity and irregular meiotic behaviour of chromosomes. The significance of these results to selection and hybridization programs aimed at the improvement of native grass species will be discussed.

SELECTION OF NATIVE GRASSES OF ALBERTA FOR IMPROVEMENT OF BIGHORN SHEEP WINTER RANGE.

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The south-facing, steep, snow-free slopes utilized by Rocky Mountain bighorn sheep present a hostile environment for range improvement by reseeding. The selection of suitable species and genotypes of native Alberta grasses has been in progress since 1974. More than 2,300 plants representing 13 species of range forage plants common to the mountains were transplanted to 18 different test sites along a 750-km stretch of the eastern slopes of Alberta's Rocky Mountains. Ability of these grasses to survive and reproduce in areas far remote from their sites of collection seems to indicate that mountain grasses have a wide adaptability. Results from broadcast seeding indicate that seedling establishment is the biggest barrier to natural and artificial range improvement. Wildlife sanctuaries which prohibit hunting and domestic animal grazing are suggested for badly deteriorated bighorn sheep winter ranges being considered for range reseeding.

MAJOR CRITERIA AND PROCEDURES FOR SELECTING AND ESTABLISHING RANGE SHRUBS AS REHABILITATORS OF DISTURBED LANDS.

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Shrubs are a resource of increasingly greater importance for the range and wildlife manager. Their value lies in the extreme variabilities that exist naturally in these plant species, and in the biotypes that thus can be matched to specific environmental conditions. Because of their adaptation to drought and salinity, shrubs deserve a high priority for selection and improvement work relative to rehabilitating disturbed land in arid and semi-arid regions of the world.

Several criteria are essential in selecting shrubs for land rehabilitation. These criteria include: (1) environmental extremes represented among the sites to be rehabilitated; (2) variability within a shrub species and its natural biotypes; (3) uses intended; (4) availability of sufficient plant material, (5) likelihood of success in artificial field establishment; and (6) potential for natural reproduction.

Procedures for establishment must fit the species used and environmental conditions. On harsh sites, transplanting of shrubs as bare-root seedlings or as container-grown plants may be preferable to direct seeding.

INSECTS THAT REDUCE REDSTEM CEANOTHUS SEED PRODUCTION IN IDAHO.

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Redstem ceanothus (*Ceanothus sanguineus* (Pursh) DC.) is a highly nutritious component of big game winter ranges in the Northern Rocky Mountains, where it comprises up to 35 percent of elk diet. Prescribed burning is recommended for rejuvenating brushfields that have become decadent due to exclusion of wild-fires. However, rehabilitation of unproductive ranges depends, in part, on availability of viable redstem seeds.

We sampled mature fruits to determine the proportions of seeds that were sound (viable), insect-infested, or otherwise unsound (hollow or shriveled). Seeds were examined by radiography and the accuracy of diagnosis was checked by dissection. During 1975-1977, sound seeds varied from 2-34 percent; whereas insects infested 9-27 percent, and unsound seeds made up 52-87 percent.

The gall midge (*Asphondylia ceanothi* Felt) destroyed reproductive buds. Fruits and seeds were eaten by larvae of a wasp (*Eurytoma squamosa* Bugbee); a weevil (*Phyllotrox rutilis* Fall); and gelechiid caterpillars. Damage caused by these insects is

described along with their seasonal history. Large numbers of a psyllid (*Arytania ceanothi* Crawford) occurred on inflorescences and may be responsible for some undeveloped fruits or shriveled seeds. Knowing how insects affect redstem seed production will aid in shrub management and production of viable seeds.

DROUGHT AND TEMPERATURE EFFECTS ON THE ESTABLISHMENT OF BLUE GRAMA SEEDLINGS.

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Bouteloua gracilis seedlings frequently die from drought even when the seminal root has extended into moist soil. If adventitious roots are not initiated soon after emergence, water uptake and, consequently, the amount of leaf area that can be kept alive is limited. Attainment of the limit to water uptake and green leaf area establishes a unique degree of seedling drought stress because seedlings are then vulnerable during sudden increases in atmospheric drought. This critical condition of drought stress can be sustained and defined in quantitative terms. Great variation among seedlings in characteristics that contribute to drought resistance reveals opportunities for seedling improvement by recurrent selection. The critical condition of seedling drought stress is alleviated with the development of one or more adventitious roots, which require 2 to 4 days with a moist soil surface and temperatures ranging from 15-30 degrees C. Adventitious roots elongate more rapidly, penetrate more deeply, and have higher capacity for water uptake than the seminal root. Consequently, the initiation and extension of adventitious roots is crucial in seedling establishment.

SOME FACTORS AFFECTING ESTABLISHMENT AND GROWTH OF BLACK BLUEBUSH (*MAIREANA PYRAMIDATA*) IN WESTERN NEW SOUTH WALES.

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Establishment patterns, survival and growth of black bluebush (*Maireana pyramidata*) were monitored near Menindee in western New South Wales for 22 years. Studies were conducted on shrubs growing on scalded loam and deep sandy soils, which are highly susceptible to erosion. Domestic livestock were excluded. During the study period, wide climatic variations occurred commencing and ending with three-year wet periods and with a 10-year mid-period of prolonged drought conditions. Germination was related to favourable wet periods. A favourable climatic period of at least 18 months was then critical for shrub establishment. Once established, plants had the capacity to withstand severe drought. Critical shrub density was required to protect the soil from wind erosion. Once achieved, large increases in plant numbers took place. The total number of established plants then remained remarkably constant despite large fluctuations of seedling numbers. Some patterning of seedlings about

established plants was evident, but plant distribution tended towards randomness with time, probably due to the competitive advantage of existing plants. Plant size was related to age. However, difference in size and shape of plants at each site reflected different site potentials for growth.

Results show that, in the absence of grazing, at least 18 months of favorable climatic conditions are critical for the establishment of black bluebush, but once established, plants are able to survive and offer protection to the soil from wind erosion for long periods.

GERMINATION REQUIREMENTS AS DETERMINANTS OF SPECIES COMPOSITION OF ARTEMISIA RANGELAND COMMUNITIES.

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The germination process has been recognized by several authors as a selective filter that often determines species composition of rangeland communities. Our purpose was to examine the function and relative importance of specific ecological parameters that compose the germination filter. The inherent physiological system of the seed interacts with the physical environment of seedbed to control germination. The seeds of different species have markedly different germination systems. We have illustrated these differences with germination data on the ubiquitous colonizer Russian thistle (*Salsola iberica*), the annual seral dominant downy brome (*Bromus tectorum*), and the perennial shrub bitterbrush (*Purshia tridentata*). The most efficient inherent germination system was limited only by the physical potential of the seedbed. Available moisture, hydraulic conductivity from the substrate to the seed, the moisture gradient from the seed to the atmosphere, light, and temperature are the physical parameters controlling potential for germination. These parameters can be modified on rangelands through manipulation of litter, soil coverage of seed, and seedbed microtopography. Manipulation of seeds and seedbeds truly offers the potential to control species composition of rangeland communities.

ECOLOGY OF ALFOMBRILLA.

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Alfombrilla (*Drymaria arenarioides* H.B.K.) is a poisonous plant that has caused severe damage to the cattle industry in Chihuahua, Mexico. This plant is a potential problem in the United States because it has been found growing near the New Mexico-Chihuahua and the Arizona-Sonora borders. A joint Mexico-United

States research program has been initiated to generate information on control and to prevent livestock losses. Alfombrilla is well adapted to soils and climates within the *Bouteloua-Aristida* type, but can grow at altitudes ranging from less than 100m to more than 2,200m. It grows best in sandy soil of acid nature (pH 5.6 to 7.2) but has been found in soils with pH as high as 9.0. Germination rate of freshly harvested alfombrilla seed is less than 5 percent; however 20-month old seed germinates at more than 75 percent. Minimum, optimum, and maximum temperatures for germination are about 10, 17, and 35 degrees C, respectively. Alfombrilla vegetative growth under alternating day-night temperatures of 26 and 15 degrees C was greater than at 32 and 21 degrees C. However, under both temperature conditions floral buds were detected 35 days after planting, and first flowers opened after 50 days, producing seed 73 days after planting.

THE INVASION OF WEEDS INTO MEDITERRANEAN PASTURES.

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In the humid northwestern parts of Tunisia the traditional form of pasturing on natural grassland and in the forest in future will be supplemented by sown pastures. This study was carried out on 2 different forms of pastures, e.g., pastures containing *Lolium rigidum* and *Trifolium subterraneum* and pastures with *Festuca arundinacea* with and without *Trifolium fragiferum*. The properties of the soil were reflected in the plant communities to be found. The main reasons for the often very quick and heavy invasion of weeds were the following: the different properties of the soil according to texture and water regime, pH and nutrient content of the soils, insufficient preparation of the seed bed, inadequate methods of sowing, unsuitable cultivars of the sown species, and adverse weather conditions. However the predominant reasons for the deterioration of the swards had their origin in a mismanagement of the sowings and the stands, e.g., overgrazing, grazing in winter-time when the soils were very wet which led to heavy poaching, weed control with wrong herbicides at the wrong time, but partly also in diseases and insects attacking especially the legumes.

By avoiding the mistakes and trying to overcome some of the natural disadvantages the output of the pastures can be greatly improved.

GERMINATION BEHAVIOR OF SOME ECOTYPES OF ANJAN GRASS (*CENCHRUS CILIARIS*) UNDER DRY STORAGE AND PHYSICAL STRESS.

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Cenchrus ciliaris (Cc) occurs in semi-natural grazing lands in Western India, where the climate is arid to semi-arid to marginal dry subhumid. In its area of distribution, Cc plants exhibit large morphological variations in habit and spike characters. Genealogical studies segregated 25 populations of Cc, called 'ecotypes' since the populations are highly correlative to climatic and edaphic complexes and have a definite pattern of distribution. Is there any seed

dormancy, if so, then why; is germination behaviour an ecotypic character; and is the process of germination the same in the ecotypes of arid areas, experiencing higher temperature during the growth period and having soils at higher matric potential (mp) and in the seeds of semi-arid ecotypes, with lower mp and higher osmotic potential (op), formed the aims of the study conducted with seeds of Cc ecotypes RM 1, 5, 7, 7A, 9, 11, 12, 13, 14, 17, 18 and 19.

Freshly collected seeds, both with and without glumes, have low percentage germination, perhaps due to the presence of phenolics. Dry storage for 2 months and 1, 2, and 3 years (with and without glumes) increased germinability of all the studied ecotypes. The skewness of the germination curves was mostly -ve. Kurtosis was maximum in RM 19 (without glumes) and RM 13 (with glumes). Temperature treatment (20, 30, 40 C) clearly brought out the ecotypic differences. Under varying soil mp, apart from ecotypic differences, the other interesting result was peakedness of germination of RM 5 and 7 seeds (without glumes) under 100 cm mp. Germinability decreased under higher op. RM 9 and 14 had high peakedness at medium op. \bar{x} is mean time to germination and its interaction with skewness has yielded interesting conclusion regarding fitness of seeds to varying soil moisture stress present in nature.

PHYSIOLOGICAL FACTORS INFLUENCING PERENNIAL GRASS DYNAMICS IN A SEMIARID GRASSLAND COMMUNITY, QUEENSLAND, AUSTRALIA.

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The perennial grasses (*Aristida* spp.) are invaders of the fertile Mitchell (*Astrebli*a spp.) grasslands of semiarid Queensland. Although periods of prolonged soil water deficit substantially reduce *Aristida* densities, little quantitative information exists on the environmental factors that influence population change.

A growth analysis study examined the seedling and early vegetative growth of white spear (*Aristida leptopoda*) and curly Mitchell grass (*Astrebli*a lappacea) at constant temperatures of 20, 25, 30, and 35 degrees C. Yield of both species increased up to 30 degrees C and then declined. At temperatures 30 degrees C and greater, both seedling growth and root extension rates were far superior for Mitchell than white spear grass. However, at temperatures of 25 degrees and less, little species differences in these rates existed. White spear required a lower soil phosphorus concentration for optimum growth compared with Mitchell grass, and its yield response to increasing phosphorus concentration was much smaller than Mitchell grass. Relative drought survival of established plants of these species was found to be related more to the amount and vertical distribution of the root system than stomatal control; leaf resistance increased as leaf turgidity declined but there was little species variation. Root standing crop values of 1,600 kg/ha and 4,400 kg/ha were recorded for stands of white spear and Mitchell grass respectively. Moreover, the former stand had a much greater proportion of its root system in the surface horizon.

As temperature has a marked influence on seedling competitive ability, these results suggest that the time of year in which significant rainfall events

occur may be an important factor controlling species establishment, and hence pasture composition, in degraded Mitchell grasslands.

CLIPPING EFFECTS ON PRODUCTION AND CARBOHYDRATE RESERVES OF BLUE GRAMA AND WESTERN WHEATGRASS.

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A greenhouse study was conducted to determine effects of frequency and height of defoliation on blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) and western wheatgrass (*Agropyron smithii* Rydb.). Plants were clipped every two, four and eight weeks at two stubble heights. The frequency of clipping significantly reduced aboveground production of western wheatgrass, but had little effect on blue grama production. Height of clipping affected aboveground and belowground production of western wheatgrass and belowground biomass of blue grama. The biomass of crowns and roots of blue grama was reduced by the more frequent defoliations, whereas only root biomass of western wheatgrass was affected. The percentage of total nonstructural carbohydrates (TNC) in blue grama was little affected by clipping treatments. TNC in crowns of western wheatgrass was reduced by frequent clipping. However, total carbohydrate reserves in roots and crowns of both species decreased when plants were clipped every two or four weeks. This probably reflected a reduction in biomass more than TNC percentage. This study was supported by EMBRAPA (Brazil) and Colorado State University Experiment Station.

EFFECT OF RANGE SITE AND RANGE CONDITION ON THE HEIGHT AND LOCATION OF THE SHOOT APEX IN VEGETATIVE SHOOTS OF WESTERN WHEATGRASS.

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Western Wheatgrass (*Agropyron smithii*), shoots were collected from the most abundant length and leaf classes at two week intervals beginning May 15 and continuing through September 6, 1964, near Cottonwood South Dakota. At each date, samples were collected from a clayey drainage-way in good range condition, clayey upland in good range condition, and a clayey upland in poor range condition. Each study area was fenced and replicated three times. The length of each shoot, number of leaves per shoot, distance from shoot base to apical meristem, and position of the apical meristem were recorded. Changes in the height and position of the apical meristem closely paralleled changes in shoot length and leaf development on all study areas. Apical meristems from the drainageway were elevated within reach of grazing animals earlier than shoots from the upland, averaging about 9 cm higher by August 7. Shoots from the site in poor condition emerged about one month later, grew and developed slower and remained shorter (34 vs 21 cm) than those from the same site in good condition. Maximum elevation of the apical meristem was reached later (August 7 vs July 22) at a lower height (5.9 vs 16.8 cm) and became dormant earlier on the site in

poor range condition. Apical meristem height and location were significantly related (p less than 0.01) to shoot length and leaf number. Coefficients of discrimination (R^2) were 0.914 and 0.805, and 0.804 and 0.755 for height and location of apical meristems in good and poor range condition, respectively.

WOODY FORAGE SPECIES IN THE SAHEL: THEIR BIOLOGY AND USE.

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The trees and shrubs of a Sahelian site in Senegal were studied for seven consecutive years, which included a period of exceptional aridity. The five dominant species had a combined density of 130 individual plants per hectare. Their total above-ground biomass was close to 2,000 kg/ha. All species were browsed by domestic animals. The average annual production of leaves and fruit was 120 kg/ha of protein-rich (10-20 percent) dry matter, and indispensable complementary feed in the dry season.

During the 1972-73 drought the number of individual plants of Guiera, Commiphora and Acacia was reduced by 50 percent, whereas the other species showed a perfect adaptation to climatic fluctuations. The productivity of woody species was sharply reduced in 1972 (30 kg/ha) as well as in the following year. Under these conditions, 30 hectares per head of cattle would have been necessary to ensure survival, whereas in normal conditions seven hectares would be required.

PHYSIOLOGICAL RESPONSES OF TUNDRA PLANTS TO SIMULATED GRAZING UNDER LOW-NUTRIENT FIELD CONDITIONS.

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The physiological response of plants to grazing has been studied primarily under artificial greenhouse conditions where nutrients are non-limiting. These short-term experiments may not properly reflect plant response to grazing under natural conditions, particularly in the case of long-lived perennials. Two tundra sedges, Eriophorum vaginatum and Carex aquatilis were studied in tussock tundra of northern Alaska, an area where plant growth is known to be limited by low availability of soil nitrogen and phosphorus. Aboveground parts were clipped at varying intensities and the plant response monitored. Regrowth of shoots with high nutrient content continued, even after six consecutive weekly clippings. Root growth was not inhibited except at the most intense clipping level. Root weight per unit length decreased with clipping, as available carbohydrate reserves were utilized, but root mortality did not increase except with the most intense clipping treatment. Phosphorus uptake rate significantly increased in roots of clipped plants. I conclude that under field conditions, grazing of these tundra species stresses nutrient reserves more strongly than carbohydrate reserves and that, in contrast to previous greenhouse studies, grazed plants respond morphologically and physiologically to increased nutrient uptake.

RESPONSE OF SIDEOATS GRAMA GROWN IN DIFFERENT SOILS TO ADDITION OF THIAMINE AND BOVINE SALIVA.

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The grazing animal exerts a definite influence on grasses and grasslands. The extent and magnitude of this influence depends on a great number of variables. Recent research has indicated that grazed plants have faster regrowth rates and produce higher yields than plants harvested mechanically. As animals graze, they leave small amounts of saliva on the foliage; and several researchers have found that certain constituents in animal saliva, such as thiamine (vitamin B₁), have brought about a favorable plant response. Recent research has shown that additions of both animal saliva and thiamine will increase plant yields. This benefit is evident primarily when the plant is subjected to extreme or detrimental environmental conditions such as drought, cold or low soil fertility. This study was set up to determine the effect that three different soils have on plant response when bovine saliva and thiamine are applied to seedling sideoats grama (Bouteloua curtipendula (Michx.) Torr.) plants.

Additions of both bovine saliva and thiamine resulted in significantly higher plant yields when plants were grown in a sand than when grown in fertile clay soils. Plant root growth was also stimulated by additions of thiamine and bovine saliva. This study has shown that a positive plant-animal-soil relationship does exist. Under certain soil conditions or otherwise depleted farm or rangelands such as are common throughout the world, one might expect an actual increase in plant vigor or yields from additions of thiamine or from good grazing management. The complete exclusion of domestic livestock from places such as wilderness areas may eventually be harmful to existing grassland associations.

AUTECOLOGY OF CURLLEAF MOUNTAIN MAHOGANY (CERCOCARPUS LEDIFOLIUS).

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Curlleaf mountain-mahogany (Cercocarpus ledifolius), a small hardwood, evergreen tree was studied to provide information primarily on germination and initial seedling growth characteristics. The species is highly valued for forage and cover by livestock and wild ungulates. Yet, little data has been presented in literature for managers to use in productively maintaining this species.

Exceptional germination resulted from moist treatments at 4 degrees C for 170 and 270 days (98 and 100 percent, respectively), and a 15-minute soak in a 30 percent solution of H₂O₂ (74 percent). This concentration of H₂O₂ may partially inhibit seedling growth. Spring germination from seed planted in the fall was 24 percent. Total and partial embryo excision indicated two possible germination deterrents: mechanical impedance by the seed coat or a gas dif-

fusion block by the membrane surrounding the embryo. The latter seemed the most likely deterrent. A pronounced specialization was demonstrated for rapid root growth in relation to top growth of seedlings following germination, indicating a high potential for reestablishment of natural stands in the face of severe competition. Seedling stem diameter immediately above the root crown was an indicator of root vigor. Seedlings with the largest diameter stems were deepest rooted.

RESPONSE OF CURLLEAF MOUNTAIN MAHOGANY TO TOP PRUNING IN SOUTHWEST MONTANA.

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In spring, 1976, personnel from the Darby Ranger District used chain saws to top-prune about 24 ha of curlleaf Mahogany (*Cercocarpus ledifolius*), a staple food for Mule Deer (*Odocoileus hemionus*), on steep, south facing slopes the West Fork of the Bitterroot River. Shrubs 3 to 4 m tall and up to 15 cm basal diameter were pruned to about 1.2 m, leaving at least one live green stem below the cut. Response was measured by clipping current annual growth (CAG) from selected (prior to treatment) plant pairs, one pruned, the other unpruned. Samples were oven-dried and weighed. In the first growing season after treatment, pruned shrubs produced about 315 percent available CAG compared to unpruned shrubs. Available CAG was increased about 60 kg/ha at a cost of about \$124/ha.

BIOGEOGRAPHY OF FOURWING SALTBUSH.

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The principal forms of *Atriplex* having fruits with four conspicuous wings are: (1) diploid, tetraploid and hexaploid *A. canescens*, (2) *A. garrettii*, (3) *A. navajoensis*, (4) *A. linearis* (5) *A. canescens* ssp. *aptera* (6) *A. prosopidium* and (7) *A. stewartii*. Of these *A. garrettii*, *A. prosopidium*, *A. stewartii* and *A. navajoensis* are narrowly endemic species.

A. linearis is a southern species abundant in Arizona, southern California and Old Mexico. *A. canescens* ssp. *aptera* is a northern species growing along the Missouri River drainage system in Montana, southern Alberta, North and South Dakota, eastern Wyoming and northwestern Nebraska. *Atriplex canescens*, the most widespread of all fourwing species, is sporadically common from southern Montana to San Luis Potosi, Mexico. Although constant for many characteristics it shows considerable variation from site to site. Some of this variation is due to autopolyploidy but most of it is due to interspecific hybridization with other species contacted in various parts of its distribution. Some products of such interspecific hybridization have precipitated as new adaptive allopolyploids, others as adaptive recombinants.

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FACTORS AFFECTING FRUIT FILL AND SEED GERMINATION OF FOURWING SALTBUSH (*ATRIPLEX CANESCENS* (PURSH) NUTT.).

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Fourwing saltbush fruit were collected from ten sites on the Jornada Plain in Southern New Mexico. Collections were made from ten plants at each site. Choice of sites depended on proximity of fourwing saltbush plants to permanent rain gages. Rain gages were selected to obtain as large a difference in precipitation as possible from site to site in a single year.

Observations were made at the time of collections to the amount of fruit produced per plant in proportion to plant size. Ratings per plant were made according to amount of cover of fruit over the plant and abundance of fruit per branch.

These studies indicated that fourwing saltbush exhibits wide variation in fruit fill, seed and fruit germination from plant to plant and from site to site. Total annual rainfall or combinations of rainfall by months did not serve to predict either fruit fill or germination of fruit or seed. Abundance of fruit produced per plant was also of no value in predicting these characteristics.

PRODUCING FOURWING SALTBUSH SEED IN SEED ORCHARDS

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Shrub seeds used in rehabilitation programs are conventionally collected from natural stands. We believe some additional high quality seed could be produced on agricultural lands. Fourwing saltbush (*Atriplex canescens*) is a case in point. Four years' seed production data from a half-sib family of fourwing saltbush indicates this land use could compete economically with other land uses as, for example, dry-land wheat production. We suggest seed production can be enhanced by an orchard design that incorporates spacing for plant growth and convenient seed harvest, a female:male ratio for adequate pollen production and dispersal and maximum seed production, and a mixture of accessions to ensure a broad genetic base and potential adaptiveness in a variety of areas to be seeded. Such an orchard design would use cuttings from parental stock proven to be consistently superior in desired traits; i. e., seed fill, growth form, and forage yield. We will contrast the performance of seed-produced plants with the potential performance of clones produced from cuttings. The subdioecious nature of fourwing saltbush would need to be taken into account in selecting parental plants because some plants are known to be inconsistent in type of flower (female or male) and hence also in seed production.

SOME ENVIRONMENTAL FACTORS DETERMINING GROWTH OF
ATRIPLEX POLYCARPA IN CALIFORNIA, AND A. REPANDA IN
CHILE.

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The present research is part of a study focused on increasing primary and secondary production under arid range conditions by modifying the flora, but maintaining the polistratified vegetation type that dominates many arid communities of Mediterranean Chile and California. A field survey was performed in both regions to determine the most important environmental factors related to distribution and other plant parameters of two saltbushes: Atriplex polycarpa (Torr.) Wats., and A. repanda Phil. These species are important browse producers for domestic animals, besides providing food and protection for wildlife in sites where the establishment of traditional forage plants is endangered by droughts. They supply green fodder rich in proteins when annual plants are dry.

In order to know their present and potential growth area, factors related to soil, relief, associated species, and man activities were considered in relation to plant variables, such as presence, frequency, density, cover, and other parameters.

The present distribution within the area of climate tolerance is essentially determined by competition. More aggressive species displace these two saltbushes to drier and more saline environments. Edaphic features, as well as overgrazing, burning, and cultivation have also been important factors

PHOTOSYNTHETIC RATES OF HONEY MESQUITE IN SEMIARID
GRASSLANDS.

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Apparent net photosynthesis of honey mesquite growing in the TransPecos Region of west Texas was measured at four times during the 1977 growing season. The peak CO₂ exchange rate observed during all sample periods occurred in early June (28.6 mg CO₂ dm⁻² leaf area hour⁻¹). The normal range of net photosynthesis for C₃ plants is 10-30 mg CO₂ dm⁻² hour⁻¹; however, leaves of deciduous woody plants normally have rates below 15 mg CO₂ dm⁻² hour⁻¹. Therefore, the relative photosynthetic efficiency on a leaf area basis is high in honey mesquite. Peak assimilation rates decreased and were reached earlier in the morning as the growing season progressed. This reduction in net photosynthesis might be explained by increased plant water stress resulting in stomatal closure and higher resistance to CO₂ diffusion. The reduction as the growing season progressed might also be partially explained by reduced efficiency of the leaves as they progressed toward senescence. The photosynthetic process in honey mesquite appears to be light saturated at about 50 nEinstein cm⁻² sec⁻¹. Optimum temperature for photosynthesis in honey mesquite, as observed in the field under high light levels, was approximately 30 degrees C. However, sustained net photosynthetic rates of 15-25 mg CO₂ dm⁻² hour⁻¹ were observed at temperatures exceeding 35 degrees C under certain conditions.

WATER RELATIONS OF HONEY MESQUITE-- A FACULTATIVE
PHREATOPHYTE.

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Honey mesquite (Prosopis glandulosa var. glandulosa) is a woody plant that occupies much of the rangeland in the southwestern U. S. and is adapted to a wide range of environmental conditions. It is adapted to both wet and dry sites and reportedly "robs" many plants of soil water.

Honey mesquite responds to the environment as a facultative phreatophyte. When soil water is plentiful, transpirational loss is high; but when soil water is limited, transpirational loss is minimal. Although transpiration is primarily dependent upon the soil water content, it is influenced by a complex inter-relationship of many factors. Mesquite apparently compensates for low soil water potentials by maintaining a relatively high internal water potential. It relies primarily on a shallow root system as long as soil water is available in the upper portion of soil, but it seems to depend on its deep root system during extended droughts.

The results reveal the influence of soil water on internal water potentials of mesquite and the influence of site on water loss through transpiration. These results provide a basis for making decisions relative to controlling mesquite to increase water yield and as a basis for making managerial decisions involved in the ranching industry

XYLEM PRESSURE POTENTIAL AND GAS EXCHANGE
PHENOMENA OF HONEY MESQUITE

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Xylem pressure potentials and gas exchange phenomena were measured in situ on honey mesquite (Prosopis glandulosa Torr var. glandulosa) of the semiarid Trans-Pecos Region near Crane, Texas. Xylem pressure potentials were measured concomitantly with CO₂ assimilation to determine the relationship of daily water stress patterns and net assimilation. Xylem pressure potentials and gas exchange rates were estimated using a pressure equilibration chamber and portable gas exchange system, respectively.

Typically, xylem pressure potentials ranged from -15 bars to -35 bars throughout a diurnal period. The maximum pre-dawn pressure potential observed was -11 bars. The maximum photosynthetic rate for honey mesquite in late spring was 28.6 mg CO₂ dm⁻² hr⁻¹ with xylem pressure potential of -28 bars. Two independent measurements showed assimilation rates of 10.3 and 20.9 mg CO₂ dm⁻² hr⁻¹ occurring at xylem pressure potentials of -39 and -31 bars, respectively. As the growing season progressed the maximum daily net photosynthetic rate decreased and occurred earlier in the day. The seasonal shift in net photosynthesis was attributed to increased water stress.

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Section 6. Rangeland Animals

PROTEIN SOURCES FOR CATTLE WINTERED ON BLUE GRAMA RANGE.

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Nine protein sources were compared for 3 years as winter supplements for yearling heifers grazing blue grama range. On the loamy plains range site weight gains tended to increase as level of protein increased, but the economic value of protein supplementation was questionable compared with grain supplementation. On the overflow site protein supplementation was uneconomical compared with grain supplementation. Dehydrated alfalfa meal generally produced the same rates of gain as cottonseed meal. However, on loamy plains a low level of dehydrated alfalfa meal produced greater gains than cottonseed meal when fed isonitrogenously and isocalorically. Three supplements containing "slow release" nonprotein nitrogen (Starea, biuret, and isobutyldiurea) produced the same gain as a low-protein cottonseed supplement supplying 60 percent as much protein equivalent. A liquid supplement supplying 230 g of protein daily produced no greater gain than a grain supplement supplying 40 g of protein and less energy. No supplement affected health or pregnancy rates of the heifers.

INTAKE AND RESPONSE TO PHOSPHORUS SUPPLEMENTS BY RANGE CATTLE.

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Many soils of tropical Australia are notoriously deficient in phosphorus, as are the forage plants grown on them. Despite the widespread use of phosphorus supplements, available evidence shows little response by cattle to these licks. The present work was designed to evaluate this costly practice and to quantitate any response under range conditions.

Individual animal intakes of phosphorus supplements were measured in two groups of free ranging cattle using a radioactive tracer technique. Live-weight and reproductive responses to supplements were analysed by regression analyses. In the first experiment, in which 200 two- and three-year old heifers were used, there was no response to the supplement although intakes ranged from 0 to 33 g of phosphorus per head per day. In this experiment, intakes were estimated twice and individuals ranked consistently in their level of intake at each measurement. In the second experiment, 250 two-year old heifers grazed pastures of lower phosphorus content. They had similar intakes of supplement to the first group, but showed positive growth responses to increase intake of supplement.

Animals in the second experiment were mustered only once after commencement of the experiment, indicating the simplicity and power of the tracer technique in determining supplement intakes.

MEASUREMENT OF DIETARY INTAKE OF PHOSPHORUS BY GRAZING SHEEP USING ^{32}P .

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A method of labeling salivary phosphorus with was used to estimate dietary phosphorus levels of grazing oesophageal fistulated sheep. This is compared with estimates made using botanical composition and species phosphorus level. The nutritional aspects of the intake phosphorus levels are discussed. It is concluded that the isotope method of estimating dietary phosphorus levels is both time saving and accurate when compared to other available methods.

DISTANCE TRAILED TO WATER AND LIVESTOCK RESPONSE.

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Factors determining location and distribution of stock watering points are considered in the light of animal physiology and behavior, and economic and management considerations. The effect of trailing sheep and cattle long distance to water is reviewed with special emphasis on the author's work on sheep. Distance walked per day, time and frequency of drinking, volume of water consumed and activity

patterns are considered from a series of experiments with sheep of contrasting age and physiological status.

The primary purpose of the studies reported was to assess the benefits that might accrue in animal productivity (weight, gain, lamb survival) by providing closely spaced water points. Energy saved during stress periods could be critical to survival and reproduction.

For Merino sheep drinking once daily, watering points could safely be placed 15 km apart since such sheep have been shown to walk about 8 km/day. Other breeds such as Dorset Horns can't tolerate such long trailing distances. Similarly, pregnant or lactating ewes are less tolerant of long distances.

Interactions occur between efficiency of water use, water point distribution, vegetation type, topography, and animal productivity. The management implications are discussed.

THE NATIVE CAMELOID SPECIES OF THE HIGH ALTITUDE ANDEAN RANGELAND.

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This paper discusses the distribution of domesticated native Andean cameloids, the llama (*Llama glama*) and the alpaca (*L. pacos*) in the high altitude Andean rangelands of Peru and Bolivia. It demonstrates the advantages that these species possess over introduced animals, especially sheep, for the production of meat and fiber, and examines the paradoxical reduction in their population and distribution. An examination of relevant climatic and vegetational features of the Andean rangeland ecosystems shows that sheep, domesticated in middle-elevation temperature grasslands, are less well-suited to these environments. Important features of these animals include timing of estrus and birth, dentition, metabolic efficiency, dietary preferences and social behavior. Despite these advantages, cameloid species have declined in recent decades in population and distribution. Several factors have contributed to this decline, governmental policies, the relative demand for products of different species, the lack of technical advances in cameloid breeding and management, and the position of cameloid herders in regional economies. This paper stresses the importance of non-western ruminant species in rangeland economies in underdeveloped countries.

SEASONAL DIETS OF FIVE UNGULATES GRAZING THE COLD DESERT BIOME.

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Fecal material was collected bi-monthly from cattle, sheep, mule deer, antelope and feral horses from May 1975 through 1977. Six samples per species per collection period were taken. Quantitative determination of the diets by species was accomplished by examination of microhistological characteristics

of plant parts present in the feces. Sixty microscope fields were examined per sample. Cattle and sheep grazed the range from April through October annually, while deer used the area primarily as winter and early spring range. Antelope, a few deer and feral horses were present at all times. Feral horses consumed more than 90 percent grasses during all seasons sampled. Sheep and cattle consumed diets of 78 and 81 percent grasses, respectively, during spring. By summer, grass consumption had increased to 90 percent for both species. Deer consumed 30 percent grasses during spring but less than 10 percent during the other seasons. Antelope consumed 8 percent grasses in the winter but less than that during other seasons. Shrubs were important to cattle and sheep in the spring, but not during the other months. Shrubs were least important to deer and antelope in the spring, but were the major diet constituents during the rest of the year. Forbs were important only to antelope and only in the spring. Similarity indices revealed that severe dietary overlap existed among cattle, sheep and feral horses. Diets of antelope and deer were similar in summer and winter. Little overlap existed between cattle, sheep, feral horses as a group and deer and antelope.

COMPARATIVE ANALYSES OF DIETS OF CATTLE, BISON, SHEEP AND PRONGHORN ANTELOPE.

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Studies were made on shortgrass prairie in north-eastern Colorado as part of the U.S. International Biological Program Grassland Biome study. Sampling was done in fenced 12-ha and 130-ha pastures grazed either intensively or lightly. Diets of cattle, bison, and sheep were studied by the esophageal fistula technique and diets of pronghorn antelope by the bite-count method. Dietary samples were analyzed microscopically for individual plant species, analyzed chemically for important constituents, and subjected to *in vitro* digestion. Herbage available in the pasture was measured by the weight-estimate method and was calibrated by plot clipping.

Our paper will report preference analyses wherein the percent of a botanical component in the diet is compared to the percent available in the herbage. Dietary overlap and degree of selectivity for these large herbivores will be presented. Diets were studied in late spring, early summer, late summer, fall and winter in small pastures lightly grazed (average herbage standing crop $66 \pm 5 \text{ g m}^{-2}$) and heavily grazed (average standing crop $53 \pm 7 \text{ g m}^{-2}$). The effect of intensity of grazing and season on dietary selectivity is discussed. Statistical analyses were made of the influence of amount and composition of standing crop on dietary composition. Mathematical programming optimization analyses were made to determine combinations of animals to maximize vegetation use.

The paper will focus on the biological interpretation of the results of alternative mathematical formulations in the optimization problem. Various objective functions and constraints were utilized. The relationship between dietary botanical composition, chemical composition, and digestibility are analyzed by nonlinear programming techniques to predict the chemical composition and digestibility of the functional groups of plants grazed as compared to the total herbage available.

THE RELATIVE PRODUCTION FROM SHEEP, CATTLE AND GOATS ON TEMPERATE RANGELANDS IN AUSTRALIA.

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The temperate rangelands of Australia are grazed by either sheep, cattle, goats or native kangaroos; and each animal has various behavioural or production characteristics that are suited to particular types of vegetation. Recent research indicates the extent and nature of these characteristics. This shows that cattle diets contain less crude protein than those of sheep, while goat diets contain more unpalatable shrubs. The growth rate of goats is much less than that of sheep, but they have a higher reproductive rate. The production of wool is less seasonally variable than that of meat, and cattle require more water than sheep or goats. In total these differences suggest that sheep will be the most productive in temperate rangelands. However, goats have a place in the control of unpalatable shrubs and cattle have a place where water and management facilities are not developed.

THE IMPLICATIONS OF GOAT, SHEEP AND CATTLE DIETS TO THE MANAGEMENT OF AN AUSTRALIAN SEMIARID WOODLAND.

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The diets of goats, sheep and cattle in a shrub-invaded Eucalyptus populnea semiarid woodland were directly observed on eight occasions on three different vegetation conditions between August 1974 and June 1976. The diets were subjected to canonical variates analysis, which showed the animal species to be selecting significantly different diets at every comparison made. Thus at any one grazing pressure a multiple species herd would spread that pressure more equitably among plant species than a monospecific herd. Identification of the plant species influential in the dietary separation is an essential prerequisite to designing experimental managements employing more than one animal species; but diet studies are not a substitute for such experiments. Due to the low value of goat and cattle products compared to those of sheep, the advantages of multiple animal grazing would have to be large to offset the dietary overlap among the three species. Although goats browsed more than sheep or cattle, the species browsed were acceptable to all stock and were particularly valuable as drought feed; thus goats tended to remove species that are potentially feed for sheep during drought. On the other hand, browsing on the leaders or young trees by cattle tended to increase browse availability for smaller stock. Competition among animal species also existed for most forage at high grazing pressures.

GOAT CONTROL OF BRUSH REGROWTH ON SOUTHERN CALIFORNIA FUELBREAKS.

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California has a special environmental problem-- 4 million ha of tough, dense brush that is designed by nature to burn periodically. Fuelbreaks are used to break up brushfields for better fire management, and for protection of urban and watershed values. Construction and maintenance of fuelbreaks is difficult and costly. Hand labor, mechanical equipment, and prescribed fire are used, and all have drawbacks. Range goats are now being evaluated for use in fuelbreak or of other vegetation type conversion.

Observation and sampling of 5- to 7-year-old chaparral regrowth during two summer browsing periods show that goats may be valuable for brush control, maintaining brush in early growth and successional stages, reducing all forms of herbaceous fuel to acceptable levels, and reducing the need for fire, herbicides, and mechanical equipment. Cercocarpus betuloides and Quercus dumosa, representing 85 percent of the brush cover, had browsing intensities of 95 and 90 percent respectively on leaf and small twig growth. With continued confinement or herding on the same area, Adenostoma fasciculatum and Arctostaphylos glandulosa were soon browsed to about the same degree. Vegetation analysis during browsing of 1-year-old shrub regrowth, with goats herded, indicate less selectivity than with older brush.

Goats are demonstrating value as a brush management tool in California, without apparent damage to the resource, while producing a salable product from the chaparral.

DINGO MOVEMENTS IN RANGELAND AREAS OF WESTERN AUSTRALIA.

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The dingo (Canis familiaris dingo) is the largest mammalian carnivore extant in Australia and has traditionally been regarded as a serious predator of sheep and cattle. In the rangeland areas of Western Australia, considerable effort has been expended on attempts to reduce dingo populations and thereby lessen the presumed threat of depredation upon livestock. However, factual knowledge on the biology of the dingo, which has only recently begun to be accumulated, is challenging these traditional beliefs and practices.

A study of the daily and long-term movements of adult and juvenile dingoes is being carried out in Western Australia. One hundred and twenty pups and adults were caught, ear tagged and released and 13 were subsequently recaptured. Since 1975, a programme of radio tracking from an aircraft has been in progress.

and 34 dingoes have been tracked for periods ranging from 6 weeks to over 12 months. Locations are being obtained during both day and night, and some animals have been located on more than 300 occasions. Visual observations are also made.

The data emerging suggest that dingoes occupy a group home range that has well defined limits. It is suggested that some of the current dingo management practices may be exacerbating the problem, and that possible changes to these practices may be proposed as a result.

THE ECOLOGICAL IMPACT OF DOMESTIC STOCK ON CHITRAL GOL GAME SANCTUARY-- PAKISTAN.

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The effects of unregulated grazing by domestic stock in Chitral Gol Wildlife Sanctuary are presented. The conditions of the habitat and the grazing potential are deteriorating. Markhor, a large wild goat, population is too small to be a contributing factor. Seasonal patterns of livestock grazing are described, and the effects of grazing are compared with ungrazed areas in remote places. Vegetation cover was studied for different seasons. Ground flora and species composition showed adverse effects of overgrazing. Forest regeneration was adversely affected, and soil erosion increased, by the removal of vegetation and trampling. The presence of graziers and their livestock is a constant threat to the existence of wild animals.

HABITAT REQUIREMENTS OF MOOSE--THE PRINCIPAL TAIGA RANGE ANIMAL.

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Moose (*Alces alces*) are circumpolar in distribution in taiga forests. They produce meat, leather and other products worth US \$100 million per annum in addition to large aesthetic and recreational values. Moose can move through deep snow and survive severe cold. Best moose ranges are shrublands, characteristic of early succession after fire or logging, interspersed with patches of coniferous forest. Moose eat hundreds of taxa of plants but locally, depend on 20-25 species, mostly woody, providing browse in winter. Carrying capacity ranges from 55-60/1,000 ha in regions with soft snow and deciduous forest, down to 12-15/1,000 ha where snows are deeper, restricting moose to 15-30 percent of the forest area in winter. Moose can be readily tamed if taken young. Profitable ranching of moose as a single land use or in conjunction with intensive production of *Populus* spp. seems feasible locally.

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MOVEMENTS AND HABITAT USE OF MULE DEER IN THE NORTHERN GREAT PLAINS, SOUTH DAKOTA.

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This paper summarizes a seven-year ongoing study of mule deer (*Odocoileus hemionus*) in the Northern Great Plains, a cooperative investigation by the USDA Forest Service, South Dakota Department of Game, Fish and Parks, and the National Park Service. It discusses home range movements, dispersal, and habitat use of mule deer in a grassland ecosystem.

Mule deer only recently returned to the Great Plains after a 50-year absence. Prevalent during the 1800's, they virtually disappeared about the turn of the century, maintaining low populations until the drought of the 1930's. After a gradual comeback, they attained huntable populations by the 1950's. Accordingly, little is known about these deer.

Unlike their mountain counterpart, Plains deer are nonmigratory; although their home ranges are larger and dispersal distances greater. Preferred habitats shared the common characteristic of rugged terrain. Twelve habitat types were delineated based on vegetation and physical site characteristics. Plains mule deer are commonly found along major river breaks--north-facing slopes dominated by Rocky Mountain juniper (*Juniperus scopulorum*), deciduous shrub and tree-covered draw bottoms, open south-facing slopes, and badlands. Deciduous tree-dominated draws are considered critical habitat because they are most susceptible to damage by domestic livestock.

THE REINDEER INDUSTRY IN SOUTHWESTERN ALASKA: PROJECTIONS FOR THE FUTURE.

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Within about twenty years after the purchase of Alaska, in 1867, the American whaling fleet had so depleted the marine mammal population of the Bering Sea region that starvation deaths among the Eskimos had become common-place. Between 1892 and 1902, in an effort to alleviate human suffering and to provide a secure resource base for the Native people of the area, Dr. Sheldon Jackson, a Presbyterian Missionary and General Agent for Education in Alaska, working in cooperation with U.S. Government, arranged for the transshipment of approximately 1300 domestic reindeer (*Rangifer tarandus*) from Siberia. Because the Alaskan Eskimos were totally unfamiliar with these animals and their husbandry, Jackson made further arrangements to bring Siberian Natives to train the Alaskans. Later, the Siberians were replaced by a team of six Lapps.

From this small beginning, the Alaskan reindeer industry was launched on a period of exponential growth culminating with ca. 640,000 head under domestication by 1930. There followed a period of rapid decline (despite the passage of the Reindeer Act of 1937) that spelled the end of the industry as a major Alaskan resource by the year 1940. Ten years later it was estimated that only 25,000 animals remained.

At the present time there are approximately 35,000 reindeer in the state, and of these none are being managed so as to produce optimal economic results.

This paper probes the underlying causes of the failure of the industry and outlines steps to be taken for its reintroduction as a modern, ecologically sound, major rangeland industry in Southwestern Alaska.

THE GRAZING ECOLOGY OF CARIBOU AND REINDEER IN TUNDRA SYSTEMS.

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Grazing in tundra systems is the focal point of ecological and socio-economic research in Alaska under the United States Man and the Biosphere (MAB) program. A major aspect of this research deals with the grazing ecology of caribou and reindeer in northwestern Alaska and includes emphasis on mapping of vegetation types through the use of satellite imagery, productivity of vegetational components of the range, selectivity of forage and vegetation types by caribou and reindeer, nutritional quality and digestibility of forage, plant responses to grazing and evolution of antiherbivore strategies, feeding behavior and associated energetics, and herd population dynamics. The work involved close cooperation among research and management organizations and exchange of scientists with Norway, Sweden, Denmark (Greenland) and the U.S.S.R. The status of this research, including a summary of findings, orientation of ongoing studies, progress in the development of a tundra grazing system model and its integration with the total Alaskan MAB program are discussed.

RELATIONS OF FOSSORIAL MAMMALS WITH ARID AND SEMIARID RANGELANDS OF ARGENTINA.

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Almost forty eight species of the fossorial Gaviomorph rodents of the genus *Ctenomys*, the so called "tuco-tuco" or "tunducque", inhabit the arid and semi-arid rangelands of Patagonia, Central and Western Argentina. Some other species of mammals are distributed in the same area and exert some kind of fossorial activity, mainly edentates ("armadillos"), cavies (a *Cynomys*-like rodent) and the rabbit-rat. Fossorial mammals have a great influence in both geomorphological and paleoecological histories of rangeland, and many of the present range conditions are highly dependent on the presence or absence of fossorial animals, mainly rodents.

The consequences of fossorial activity may be classified in more than fourteen categories, each one being favourable or unfavourable in relation with local climatic and soil conditions. Favourable consequences contribute to soil maturity and evolution, and increase fertility and primary productivity of ecosystems. Unfavourable consequences cause or promote soil erosion, produce a greater annual runoff, and destroy the plant cover. They also cause economic losses in cultivated lands and forest stands,

and compete with cattle. Unfavourable actions predominate in zones with critical conditions of aridity, semiaridity or heavy grazing.

RESPONSES OF COASTAL PRAIRIE VEGETATION AND ATTWATER PRAIRIE CHICKENS TO RANGE MANAGEMENT PRACTICES.

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Responses of the endangered Attwater greater prairie chicken (*Tympanuchus cupido attwateri*) to cover manipulation in Coastal Prairie rangeland were investigated from 1974-1976 on the Attwater Prairie Chicken National Wildlife Refuge in Colorado County, Texas. Concentration of prairie chickens on grazed pastures occurred in fall and winter. Ungrazed pastures were not used, and were characterized by deteriorating range condition. Prairie chickens respond immediately to prescribed burning and mowing treatments applied in fall and winter. Feeding use occurred throughout winter, and was greatest on fall-burned plots. Primary use of mowed plots was for booming. By mid-May, regrowth on treated plots was sufficient for concealment, escape, and roosting cover. Thirty variables were analyzed by analysis of variance to determine vegetation responses. No statistical differences were found for species composition and frequency of dominant grass and forb species. Eight structural characteristics differed significantly with treatment.

THE ROLE OF ENTOMOLOGY IN RANGE MANAGEMENT.

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Although entomology is a mature science with advanced and active subdisciplines, range insect research lags behind. Many range insects await discovery; others are discovered only in the sense that they have been named. The role played in range ecosystems is not known for some of the common insects. A major range concern is that of irregular and periodic insect outbreaks. Insects affect the vegetative, floral and seed production of range plants. Insects may act as agents or target organisms in biological control of plants and plant pests. Changes in the morphology and chemistry of genetically improved plants may affect susceptibility to insect attack.

Harmful and beneficial range insects are present. Range Management should be concerned with the extent of the presence of each. Emphasis is placed on a long lasting approach to management of insect pest populations through habitat improvement for beneficial insects (parasites and predators), and non-game wildlife. Knowledge of plant habitat requirements of beneficial insects will aid in rangeland rehabilitation. Some plants may also attract or repel harmful or beneficial range insects.

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INSECT GRAZERS ON COLD DESERT BIOME.

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The seasonal abundance of insect trophic levels was determined in several habitat types of native range on the Squaw Butte Station in Oregon. More phytophagous (plant eating) insects were present on range

under a managed grazing program with domestic livestock than on range that has not been grazed for 37 years. Root aphids and root coccids were the dominant insect grazers in the Artemisia arbuscula-Festuca idahoensis and in Artemisia tridentata-Agropyron spicatum habitats. Both the aphids and coccids were considered to be at tolerable levels, but still represent potential pests. Revegetation of the range with susceptible grasses may result in a disproportionate amount of forage being consumed by the insect grazers. Candidate grasses for use in range revegetation should be evaluated for insect resistance well before revegetation.

Section 7. Inventory and Evaluation of Range Resources

SURVEY AND EVALUATION IN THE EXPLOITATION OF RANGE RESOURCES IN THE DEVELOPING COUNTRIES - EXPERIENCES AND SUGGESTIONS FOR PROCEDURES.

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The crucial issue in the survey and evaluation of rangelands is the application of the information (inventory data as well as monitoring data) in range management programmes. Personal experience in developing countries, literature, and communications from colleagues point out that information is piling up but little action is taken. Some underlying factors are mentioned and improvement in procedures from the surveyors point of view is suggested. The decisionmakers-level should be made aware of the economic importance of the rangelands. As an example, an economic analysis for the rangelands of Iraq is presented. Local personnel in all stages and at all levels should be involved in the survey and the resulting recommendations. In this context the I.T.C. line of training and range-land survey methodology is presented. Results of survey and evaluation should be communicated to three different groups: (1) the politician-decisionmaker, (2) the rangeland-manager-user, and (3) the professional colleague. Each of them calls for different presentations of results. Work in Spain, Iraq and Tanzania is used as an illustration. The potential and the danger of new remote sensing techniques in inventory and monitoring of rangelands in the developing countries, as related to the above points, is exemplified and discussed.

NONFEDERAL GRAZING LANDS OF THE UNITED STATES--A DECADE OF CHANGE: 1967-1977.

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Probably the most authoritative inventory of non-federal rangeland in the United States is the 1967 Conservation Needs Inventory published by the U.S. Soil Conservation Service (SCS) in 1971. From a potential Cropland Study conducted in 1975, SCS was able to update much of the 1967 data concerning nonfederal rangeland. Nationwide, rangeland and pastureland increased about 26 million ha during the decade of 1967 to 1977. Six states reported a significant increase in extent of rangeland and three indicated a substantial decrease. The largest net gain in rangeland, 19.6 million ha, was from forest land; and the greatest loss, 12.9 million ha to cultivation, was more than offset by reciprocal gains from cropland. Range

conservationists estimate 12 percent of nonfederal rangeland is in excellent ecological condition, 28 percent in good, 42 percent in fair, and 18 percent in poor. As of September 30, 1977, SCS estimated 69 percent of nonfederal rangeland was properly grazed and 89 percent was adequately protected.

A VEGETATION AND CLASSIFICATION SYSTEM FOR NEW MEXICO, U.S.A.

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Increasing pressures on land has created a need for understanding our land resources and their potential. In New Mexico, land holdings are mixed with several Federal Agencies controlling nearly equal amounts of land and the private land pattern approximately equal to Federal land. The need for Interagency agreement to classifying lands to their potential while allowing for respective interpretation by agencies and other users was essential. A new General Soils Survey map was available and agreed upon as the primary base for the vegetational classification. The ability to utilize the system for comparisons to established general approaches to classification was also imperative. Mapping procedures identified the formation, region, series and association. The association is the equivalent of a management planning program, i.e., the *Bouteloua gracilis* - *Agropyron smithii* association. The use of the series and association allows for identification of potential vegetation units that are easily recognized by planners and lay persons for general usage while also allowing range specialists the ability to further subdivide into plant communities or range sites. Other land users may also subdivide the association into functional units for their respective uses. Development of the system will allow a systematic process for identifying vegetation to its simplest units while providing common nomenclature on like units of land with the same potential. Such information is mandatory for preparation of special use base maps and identifying land status in environmental impact statements. Techniques used in New Mexico, USA should be applicable in many areas of the world.

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RECOGNITION OF LAND CAPABILITY--THE KEY TO SUCCESSFUL RANGE MANAGEMENT.

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Throughout history, man has abused, sometimes severely, the natural vegetation of the earth with domestic animals. Despite the knowledge now possessed on many plant ecosystems and advancements made in range management grazing systems, abuse continues in many places with damaging and oftentimes devastating consequences to the soil and plants. This weakens the

A major cause for damaging use by domestic livestock is man's failure to fully recognize the capability of the land to withstand the impact of domestic livestock grazing. The term "rangeland" or "pasture land" has been universally applied to all natural, low-growth vegetation, and this vegetation has been used without adequate recognition of the heterogeneity of the soil, flora, geology, and terrain and without adequate consideration of the effect grazing one area has upon adjacent or nearby lands.

The key to sound use of the earth's grazable forage is a land capability and suitability determination followed by application of a management system that recognizes these characteristics. With this knowledge, the land manager can protect the delicate and sensitive areas and achieve full potential from the stable and productive sites.

THE COMPREHENSIVE RESOURCE INVENTORY AND EVALUATION SYSTEM IN THE DOMINICAN REPUBLIC.

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The Comprehensive Resource Inventory and Evaluation System (CRIES) was developed by the Economic Research Service of the United States Department of Agriculture beginning in 1976. The purpose of this system is to provide an agricultural data management system and an analytical framework for assembling resource information and assessing the supply and development potential of resources suitable or adaptable for agricultural production.

Major components of the CRIES system are: (1) an inventory of the quantity, quality, ecological characteristics, and development potential of agricultural land; (2) an evaluation of current land use, cropping and livestock patterns, and crop and livestock production technology; (3) estimates of input costs and output response expected for each crop and livestock type; (4) an assessment of alternative new crop and livestock options and production technologies; and (5) a computerized analytical system that allows all crop and livestock production possibilities to be considered simultaneously when selecting the most efficient combinations to meet alternative policies, goals and institutional changes of interest to national policy makers.

The CRIES system is currently being utilized by the Dominican Republic Secretariat of Agriculture for land use policy analysis and for assessing crop and livestock production information needs. The system will be introduced to other developing countries in the near future.

APPLICABILITY OF RANGELAND MANAGEMENT CONCEPT TO FOREST RANGE IN THE PACIFIC NORTHWEST.

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The concepts of rangeland condition, rangeland trend and associated livestock management are discussed for applicability to forest range. Traditionally, best condition is based upon climax density and composition of plants; poorer condition has resulted from livestock over-grazing. Trend is change in vegetation resulting from livestock grazing: downward trend is caused by over-grazing and upward trend by proper grazing. Livestock management objectives generally are to maintain best condition or to foster an upward trend to best condition. All three concepts apply poorly to forest range in the Pacific Northwest for two reasons: past natural underburning and timber management. Lightning caused underburning maintained grass vegetation under open ponderosa pine. With fire suppression, tree crown cover has increased causing a "downward trend". In many cases, pine is being replaced by a fir climatic climax. This condition must be based upon successional tree crown cover and cause of trend must be determined-- due to tree cover or animal use? Timber management, as it affects tree density and damage to ground vegetation can cause changes in range vegetation totally unrelated to animal use or management.

RANGE RESOURCES INVENTORY OF MENDOZA (ARGENTINA)

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Natural renewable resources of the province of Mendoza in the arid western part of Argentina have been inventoried. Its economy depends strongly on the under irrigation agriculture. Five percent of the total extension of this province is devoted to this activity, which contributes 90 percent of its gross agricultural product. The livestock production is mainly steered on cattle breeding.

The overall geomorphic and soil features allow us to estimate that cattle exploitation is suitable for about eight million hectares (55 percent of the total surface of Mendoza). The climatic conditions, although diverse due to topographic variations are not an obstacle for this activity.

The regional vegetation includes valuable herbaceous and woody forages due to their diffusion, density, fodder worth and ecologic productivity.

This study enables us to conclude that the considered territory might greatly increase its importance for beef production. This is related to the tendency to displace the traditional cattle area of Argentina towards the rangelands of the marginal zones.

The most important factors hindering this displacement are pointed out. These are: limited social and economic infrastructure, inadequate land tenure, deficient technology, and so on.

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INVENTORY AND EVALUATION OF RANGE RESOURCES IN "MAQUIS" AND "GARRIGUES" (FRENCH MEDITERRANEAN AREA): PRODUCTIVITY LEVELS.

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"Maquis" and "garrigues" are relatively stable and dense plant communities composed of sclerophyllous evergreen shrubs that prevent livestock from penetrating. These rangelands include grazing species that are not frequent and not productive. Carrying capacity is below 0.5 sheep/ha/year.

To make use and develop their spontaneous grazing productivity, we have to allow the penetration at first, and then stimulate the development of existing grazing species.

Mechanical grinding of the aerial phytomass decreases shrubs without erosion. The development of the grazing species is stimulated by considering the main limiting factor: trophic level (mainly P and N). We describe the lay-out used in a few environments ("garrigues" of *Quercus coccifera* L. and "maquis" of *Cistus monspeliensis* L.). They emphasize the measurements made during several years (cover, aerial phytomass, stocking rate) and the time necessary to reach the optimal level of productivity. This time varies with ecological conditions.

The carrying capacity of improved "garrigues" is between 3 and 5 sheep/ha/year, and the one of improved "maquis" is between 7 and 10 sheep/ha/year.

We present the background for extending the results to the ecological region level and generally speaking to the whole marginal areas of Southern France by use of relevant thematic mapping.

DILLY AREA RANGE SURVEY.

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The Dilly area is in the Sahelian zone of the western part of the Republic of Mali between the longitude 8° 10' W and 7° 20' W, the parallel 14° 30' N and the Malian-Mauritanian border. The area covers 1,313,600 ha and receives 419 mm rainfall a year. receives 419 mm rainfall a year.

The Dilly area is a pastoral zone where the herdsmen practice a migratory system for the utilization of the natural grazing land by joining with their livestock to Mauritania at the beginning of the rainy season in summer and coming back toward the southern area of the country where rainfall is higher and more forage is available later in the year.

In order to develop the area and to establish the balance between grazing animals, water, and grazing land strongly disturbed during the past Sahelian drought, a range survey was undertaken by the Government of Mali. This survey presents: (1) identification of ecological units, (2) range conditions (water, utilization, trails, burns), (3) range management (how to improve range conditions), (4) livestock marketing, and (5) an extension approach to the organization of people in rural areas.

A CRITICAL REVIEW OF SURVEY METHODS FOR RANGELAND MANAGEMENT IN THE THIRD WORLD WITH SPECIAL EMPHASIS ON REMOTE SENSING.

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The rangelands of the third world are becoming more and more the interest of modern society.

There is a wide spread deterioration on the one hand; whereas at the other the traditional users of those lands receive more and more resistance from settled agriculturists, in the most valuable parts of their dominions in the fringes. Evaluation is necessary for solving old problems and in trying to find new methods of optimal management.

Because of the economical relatively low return per ha, survey methods should be cheap. Because of the dynamic character of most (semiarid) rangeland ecosystems, survey methods should merge into monitoring.

New technology of remote sensing has been oversold during the last decade. This paper tries to separate the science, fiction and practices of the possibilities of remote sensing for rangeland survey and monitoring purposes.

Old fashioned black-and-white and some false colour aerial photographs are still most important. Satellite imagery has advantages for rough monitoring. In special cases other means might be profitable, but have up till now proved to be not really economically and practically useful, in the third world practice.

OBSERVER ERRORS IN SAMPLING ECOLOGICAL VARIABLES FOR RANGE CONDITION ASSESSMENTS.

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A discussion is given of the sources of error associated with subjective assessment procedures for ecological variables. In particular, the effects of different types of observer errors are illustrated with examples from Australian rangeland research. It is concluded that users of subjective assessment methods can easily be misled by observer differences and that more attention should be directed to this area when selecting methods for use in the management of rangeland resources.

USE OF 35-MM AERIAL PHOTOGRAPHY IN VEGETATION SAMPLING.

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A vegetation mosaic on a complex of thin-surfaced and thick-surfaced solodized solonetz soils in western South Dakota was ripped at a depth of 30 cm with either a 0.6 m (2 ft) or 1.2 m (4 ft) spacing of the ripper

shanks in the fall of 1973. Replicated subtreatments (21.3 m x 13.1 m) were superimposed on the ripping treatments. Subtreatments included a control, broadcast seeding of 2.2 kg/ha of yellow sweetclover (*melilotus officinalis*), fertilization with 44.8 kg/ha of nitrogen applied as ammonium nitrate in the fall, and broadcast seeding of 11.2 kg/ha pure live seed of a local ecotype of western wheatgrass. Response to treatments was evident but difficult to measure because of the great variability within treatments. Consequently, imagery from 35 mm aerial photography was used to stratify sampling. Imagery was collected using a 35-mm camera equipped with a motor drive and 135-mm telephoto lens. A modified camera mount was used with wing-over light aircraft, which provided the stability required for clear, high-quality imagery. Ektachrome color infrared film (ASA 133) processed in a field laboratory provided high-quality imagery available for rapid evaluation. This inexpensive system of imagery collection was used to delineate soil and vegetation pattern and to stratify subsample location, thus allowing: (1) improved efficiency in estimating effect of treatments on the standing crop of vegetation compared with non-stratified sampling, and (2) providing reduced cost in data collection due to reduction in number of samples required to sample with a given precision.

SEMIARID RANGELAND AND GRAZING EVALUATION OF SHRUBLAND FROM PERMANENT QUADRATS.

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The long-term studies of vegetation cover dynamics on grazed and protected sites in western Wyoming were initiated in 1960 with a cooperative agreement between the Bureau of Land Management and the University of Wyoming, Range Management Department. Data were obtained from 29 livestock exclosures distributed throughout western Wyoming on semiarid northern desert shrub rangelands, and at an 8 pasture research grazing study area on a gardner's saltbrush vegetation type.

Vegetation cover data were obtained from permanently located quadrats inside and outside of exclosure areas. Within the 0.6 x 6.0 m (2 x 20 feet) quadrats, crown cover of shrubs, halfshrubs, plains pricklypear and mat form species such as *Phlox hoodii*, was determined by position mapping procedures. Within 1.2 x 1.2 m (4 x 4 feet) quadrats, herbaceous cover was determined utilizing a 10-point frame with pins spaced at 5 cm (2 inches) intervals. The point frame was positioned at 10 locations within each quadrat. First hits of all species as well as ground surface character were recorded.

Data were obtained at 4-year intervals during the years 1960, 1964, 1968, 1972 and 1976. Changes of vegetation cover on the study areas were due to a combination of several factors. Grazing influences in almost all the study areas, and vegetation type difference apparently played an important part in dynamics of vegetation cover. Shrub and forb species generally increased, but grass species decreased in average cover on the grazed areas as compared to the protected areas.

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INFLUENCE OF POINT QUADRAT ORIENTATION ON VEGETATIVE ANALYSES OBTAINED ON DISTURBED LAND RESEEDED IN ROWS.

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Rangeland which had been strip-mined was reseeded by drilling a grass-legume mixture in 17.8-cm rows in spring 1973. A grazing study was initiated in spring 1976 with ungrazed, light, moderate, and heavy grazing treatments. Species composition is recorded before and after each grazing season using point frame quadrats, which are located at predetermined intervals along six permanent 12.3-m line transects per pasture. The orientation of the transect determines if the point frame is perpendicular to or parallel with the seeded row. To determine if orientation influenced readings, transects were placed: parallel, at a right angle, or at a 45-degree angle to the drill strip. A fourth treatment was completely random in which a lawn dart was tossed to determine the location for the end of the point frame. Five 10-point frames were read per transect and only one "hit" was scored per point. Observations included "dominant" species, "other" species, litter, and bare soil. F-tests indicated no significant differences due to orientation of the transect. With similar species and age stand, transect orientation, even in row-seeded rangeland, apparently does not significantly influence point frame readings.

EVALUATING LONG-TERM UTILIZATION ON WHITE BURSAE.

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Analysis of impact of feral burros on desert vegetation required that a procedure for evaluating utilization on white bursage (*Ambrosia dumosa*), a shrubby forage species, be available. Available techniques for determining the percent of current years production removed by herbivory were not well suited for use on white bursage. An alternative approach was the evaluation of "long-term" utilization which was defined as the cumulative effect of herbivory on woody vegetation. Heavy utilization on white bursage resulted in both lower overall biomass and changes in shrub morphology. Canopy volumes of shrubs are severely affected while basal diameters are relatively unaffected.

The biomass of individual shrubs was highly correlated with both canopy dimensions and basal diameters. Regression equations were developed using biomass vs. basal diameter for ungrazed shrubs and biomass vs. canopy volume for shrubs under all utilization intensities. Utilization of a shrub was then determined by comparing actual biomass predicted from canopy volume and "potential" biomass predicted from basal diameter.

Following the initial development of regression equations, the method proved to be a quick reliable procedure for quantitatively evaluating utilization patterns.

TRENDS IN STANDING CROP AND SPECIES COMPOSITION OF A RESTED KENTUCKY BLUEGRASS MEADOW OVER AN ELEVEN-YEAR PERIOD.

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Native Kentucky bluegrass (*Poa pratensis* L.) meadows provide a major source of livestock forage in central Oregon. A study was initiated to evaluate potential mid-season production and vegetation change of a rested bluegrass meadow as a basis for management recommendations. The meadow received season-long cattle use during the previous 30 years. Mid-July standing crop was sampled annually between 1967 and 1977. Species composition by loop frequency method and canopy coverage estimates were compared between rested and grazed treatments.

Standing crop doubled within the first 5 years of protection and declined to pretreatment levels by the tenth season. Noticeable changes in litter depth, percent bareground, bluegrass growth form and species composition occurred over this period.

The persistence of Kentucky bluegrass in over-grazed meadows is strongly influenced by its ability to maintain rhizome-dominated growth under season-long use. Carrying capacity can be increased by resting meadows for two growing seasons to favor tillering and deferring use until late spring of the third year to prevent flowering. Bluegrass must be grazed to maximize standing crop production. However, periodic rest is necessary to balance rhizome with tiller growth and to prevent eventual stand dominance by less productive increaser forbs and grasses.

RANGE CONDITION TRENDS FOLLOWING CONTROL OF HONEY MESQUITE (*PROSOPIS GLANDULOSA* VAR. *GLANDULOSA*) ON DEEP HARDLANDS IN NORTHCENTRAL TEXAS.

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A study was initiated in the spring of 1973 to measure ecological changes following brush control on a deep hardland range site dominated by honey mesquite in northcentral Texas. Field data and low altitude aerial photography were taken prior to treatment in spring 1973, and each succeeding spring or fall through 1976. Brush control treatments included aerial application of 2,4,5-T (2,4,5-trichlorophenoxy acetic acid) in a conventional 1:4 diesel oil:water emulsion (2,4,5-T Conv.); 2,4,5-T in a low volume 1:7 diesel oil:water emulsion (2,4,5-T l.v.); 2,4,5-T + picloram (4-amino-3,5,6-trichloropicolinic acid) (2,4,5-T + picloram Conv.); basal treatment with 2,4,5-T diesel oil mixture; and tree grubbing followed by chaining.

Tree grubbing was the most effective honey mesquite control method; followed by basal spraying, aerial application of 2,4,5-T + picloram and 2,4,5-T, respectively. There was little difference in honey mesquite control between conventional and low volume applications of 2,4,5-T.

Total herbage production varied each year according to growing season precipitation. Forb production was significantly high and grass production

lower in years with above normal precipitation. High forb production in wet years suppressed the production of warm season increaser and invader grasses, but did not influence production of warm season decreasers and cool season grasses.

Production of all perennial grasses was higher in basal and aerial spray treatments compared to the control at the end of the study indicating a trend of improving range conditions.

Tree grubbing followed by chaining reduced many established perennial grasses and encouraged the production of early successional stage plants. Range condition was poorer than pretreatment condition if only native grasses were considered. However, sideoats grama (*Bouteloua curtipendula*) and sorghum alnum (*Sorghum alnum*) seeded into areas denuded by tree grubbing compensated for native grasses lost during treatment after the third year.

GRAZING SYSTEMS FOR RANGE IMPROVEMENT AND LIVESTOCK PRODUCTION IN THE NORTHERN GREAT PLAINS.

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Several types of grazing systems are being used by North Dakota ranchers for profitable livestock production. This paper describes and evaluates systems on 10 cattle ranches in the central and western parts of the state to determine their effectiveness in improving range condition and increasing stocking rates.

The most effective management systems for range improvement were deferred rotation grazing and seasonal systems employing introduced grasses (introduced pasture) for spring grazing or combinations of both systems. A 10-year evaluation of changes in range condition showed rangelands managed with these systems were in high good to excellent range condition. Stocking rates have increased as much as 56 percent more than on similar ranges under continuous grazing. Introduced pastures grazed in the spring increased the total animal-unit-months by 18 to 36 percent on six of the ranches. Many livestock producers in this region are not fully aware of rangeland production potentials and the value of improved range management.

This evaluation showed that these grazing systems will improve and maintain the range resource near optimum levels for sustained periods. It appears a substantial increase in grazing capacity can be obtained on rangeland by using these management systems.

Section 8. Rangeland Management Practices and Systems

NON-COMPETITIVE RANGELAND MANAGEMENT FOR ANIMALS, WILD AND DOMESTIC.

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Because of increasing need for human food and recreational benefits, ranges of the world must be managed for animals (wild as well as domestic) in manners that permit a maximum in production with a minimum of competition between species.

Many nations have endeavored to introduce domestic livestock, particularly cattle, into their environments with results that are unsatisfactory or even disastrous. The animals often compete directly with species of wildlife that are better adapted to resist insect pests and disease and can survive best under local climatic conditions. When wild animals compete with livestock, there are widespread efforts at "extermination"--a conclusion that can be avoided through sound resources management. The end result of the introduction of livestock can be overgrazed range that will support only close-cropping sheep and goats; in short, a denuded and impoverished land such as now exists in parts of the Middle East and Africa.

One ray of hope is that leaders in developing countries with the appropriate resources will devise ways to use wildlife as a steady source of both food and income, without destroying it as a valuable resource. Game ranching is becoming increasingly popular in many areas. Wildlife can provide substantially more protein than domestic livestock ranging the same area. In addition, they do less damage to the range, utilizing the forage more efficiently and completely. Nature has developed a wildlife species to feed on most growing plants in the environment, including thorny trees and shrubs. Domesticated livestock utilize only a few of the more palatable species. Promoting safaris to harvest surplus game is another plan, which provides food and income for local tribes as well as the governments involved. Most widely accepted way to cash in on wildlife resources is to set up national parks and game sanctuaries, with shooting by cameras providing a lucrative tourist trade.

Many developing countries need long-range natural resource development plans. Land and water areas should be inventoried and classified. The United States could furnish competent soil and water conservationists, range management specialists, wildlife biologists, and other technicians to help.

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GRAZING MANAGEMENT TO MEET NUTRITIONAL AND FUNCTIONAL NEEDS OF LIVESTOCK.

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Although planned grazing systems rarely ignore livestock physical needs, most fail to take into account dietary and essential functional requirements of reproductive and immature animals. Manipulation of livestock for range improvement and grazing distribution generally has caused reduced grazing animal performance on native range.

Ranges supply forages of excellent quality during the rapid growth period; forages declining in palatability, digestible energy, and protein during the late growth period and plant maturity; and finally forages deficient in most desirable constituents the rest of the year.

Livestock nutritional and functional requirements are presented in the context of stocking procedures to integrate those needs with range phenology, forage quality, grazing selectivity, and plant growth requirements. Forage conversion by livestock is discussed in terms of biological and economical efficiency.

STOCKING RATE THEORY AND ITS APPLICATION TO GRAZING ON RANGELANDS.

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The Petersen-Lucas-Mott model, in which gain increases linearly with increasing area per animal (decreasing grazing pressure) to a maximum and then continues indefinitely at that maximum, has had considerable influence on range and pasture management. If we assume that this model applies to individual animals, it can be shown that in a genetically heterogeneous population in which grazing pressure influences the total amount of forage, the slope of the ascending portion of the curve decreases as area per animal increases. Thus the curve for a grazing population comes to resemble a rectangular hyperbola when gain is plotted against area per animal, or a line with negative slope when plotted against animals per area. This is the model proposed by Hart and by Jones and Sandland. However, the linear model is not completely

accurate, because gain of a population becomes constant at very low grazing pressures. Data from the literature indicate that gains of stocker sheep and cattle and of suckling calves and lambs follow the proposed model. The application of the model to determination of economically optimum stocking rate and to economic comparisons of range improvement practices will be discussed.

GRASSLAND MANAGEMENT: PRINCIPLES AND PRACTICE IN SOUTH AFRICA.

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Selective grazing among plant species and areas has contributed substantially to the degeneration of large tracts of grassveld in South Africa. Overgrazing, in contrast, has probably played a less significant role except in that selective grazing promotes the overuse of certain species or areas. Consequently research interest has concentrated largely on the prevention of selection itself or of the effects of selection. This has necessitated the development of rotational grazing procedures, of which there are two main types. High performance grazing (HPG), or controlled selective grazing (CSG), is based on lenient grazing in a rapid rotation where anticipated animal performance is good and recovery growth of the veld rapid. This rotation is best applied on veld in good condition. High utilisation grazing (HUG), or non-selective grazing (NSG), aims at a slow rotation in which veld is well utilized whenever it is grazed. This system seems best adapted to degenerate veld where animals are forced to utilize the available forage. The control of selective grazing and the long rest periods that follow each grazing may contribute substantially to veld recovery.

Continuous grazing, although providing for good animal performance in the short term, leads to a gradual degeneration of veld condition, and is therefore seldom recommended.

A HOLISTIC APPROACH TO RANCH MANAGEMENT USING SHORT DURATION GRAZING.

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Ranch situations are complex and never static. Drought, fires, cold spells and floods play havoc with grazing systems. This paper deals with a highly successful whole approach to ranch situations, with land and/or stock under communal or private ownership. The method of short duration grazing is based upon maximizing energy flow per unit of land and is applied on a grazing cell layout. Planning is holistic and systematic, embracing finance, economics and management, stock husbandry and animal behavior, and plant and soil succession. The method has been successfully applied on ranges from desert to high rainfall—from flat open plains to heavily bushed country and mountains, from small farms to million acre ranches. Ranges considered beyond reclamation are now in good heart and carrying up to three times the stock by no other measure than that of changing to short duration grazing as outlined.

MONITORING OF LIVESTOCK DEVELOPMENT SCHEMES IN SUB-SAHARA AFRICAN RANGE AREAS: THE APPROACH OF THE INTERNATIONAL LIVESTOCK CENTER FOR AFRICA (ILCA).

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In accordance with its mandate and as approved by its Program Committee and its Board, ILCA has been building up a system to monitor livestock development schemes in Africa. Tentatively there will be a network of five development schemes located in range areas south of the Sahara.

Monitoring, in ILCA's context, refers to the interdisciplinary exercise of following the important changes of livestock production systems in such development schemes. While experience is limited to 18 months at the time of writing, it appears nevertheless worthwhile to sketch: (1) the conceptual development that has taken place over this period, (2) the methodological problems ILCA has come across and the attempts to solve them, (3) the major trends and caveats that have been identified in connection with the conceptualization and implementation of monitoring exercises, and (4) the expected benefits and results of the exercise.

LIVESTOCK AND VEGETATIONAL RESPONSES TO CONTINUOUS AND 4-PASTURE, 1-HERD GRAZING SYSTEMS IN NEW MEXICO, U.S.

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A 4-pasture, 1-herd rotation grazing system was compared to continuous systems at two stocking rates. The rotation system and one continuous system was stocked 25 percent higher than the other continuous pasture. The study was conducted on piñon-juniper-blue grama grassland at an elevation of about 2,300 m in southcentral New Mexico. Average annual precipitation is about 38 cm with about 60 percent falling during the growing season from June through September. Average calf weaning weights were consistently higher for continuous grazing by about 12 kg per calf than for rotation grazing over the eight-year period. However, during the drought year of 1974, grazing was suspended on the heavily-grazed, continuously-stocked pasture because of lack of forage. Calf production per ha and percent calf weaned was similar for the three treatments. Herbage production has been consistently highest on the rotation pasture and lowest on the heavily-stocked, continuously-grazed pasture. Production of undesirable forbs was also considerably greater on the heavily-stocked, continuously-grazed pasture than on the other two pastures. Under conditions of this study, the main advantage for the rotation grazing system came from vegetational and not livestock responses.

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GRAZING RATE AND SYSTEM TRIAL OVER FIVE YEARS IN A MEDIUM-HEIGHT GRASSLAND OF NORTHERN TANZANIA.

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The effects of three grazing rates and two grazing systems on native forage species, as well as on livestock performance, were studied for 5 years near Arusha, Tanzania. Grazing study literature suggests that moderate use under a rotational system of some sort is advisable for areas with 800 mm or less of rainfall.

Heavy, moderate, and light grazing left 450, 2200, and 3500 kg/ha and utilized 87, 52, and 25 percent of the forage produced, respectively, following the long rains of the last year of the trials. Heavy grazing resulted in most bare soil and least forage production, total plants, and litter cover. Moderate and light use produced nearly equivalent amounts of forage, litter cover, and bare soil, but light use showed more total plants. Very little difference existed in terms of forage responses between continuous and rotation grazing.

Livestock weight changes depended upon the previous month(s) rainfall. Weight losses occurred in the first month of the rainy season and after extremely high rainfall months when livestock were consuming feed high in moisture. Losses also occurred in the latter part of the dry season. Only slight differences in gain per animal existed when comparing grazing rates or grazing systems. Heavy use, then, contributed 2 to 3 times higher gain per hectare than moderate use and 3 to 6 times more than light grazing.

THE TESTING OF GRAZING SYSTEMS ON SEMIARID RANGELAND IN BOTSWANA.

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Considerable interest has been generated in Southern Africa in the ability of various forms of rotational grazing to improve range condition and cattle performance under arid conditions. However, much of the information is from the subjective observations of certain farmers and research workers but very little data are available from controlled experiments. Trials were initiated in 1975 in Botswana on 3 sites in varying ecological and rainfall zones to critically compare such grazing systems. Four systems were compared namely, (1) Continuous grazing, (2) 3 paddocks, (graze for 1 month and rest for 2 months), (3) 9 paddocks (graze for 4 days and rest for 32 days), and (4) 9 paddock (grazed for 7 days and rest for 56 days). All treatments were stocked at 1 livestock unit (L.S.U.) to 10 ha and 1 L.S.U. to 8 ha in the first and second seasons, respectively. After two years there was no difference in botanical analysis, yield of dry matter or cattle performance among treatments.

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A GRAZING SYSTEM FOR SEMIARID LANDS.

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An important criterion for a grazing system in semiarid and arid regions is that it should be flexible to allow for environmental fluctuations. Successful grazing systems developed in more humid zones have often failed in low precipitation areas because no consideration was given to differences in climate, soil, vegetation and managerial practices. Any grazing system to be successful needs to be tailored to the environment and needs of the landowner. A flexible rotation system was established in 1967 on a semiarid grassland in southern New Mexico in a 225 mm precipitation zone. The primary goal of the study was to improve perennial grass production and range condition and thereby, cattle production. A regular pattern of rotation among pastures was established, but cattle were moved at any time to a pasture for short periods in order to utilize ephemeral forage resulting from local rainstorms. Livestock production was similar on the flexible system and the continuously grazed pasture. Distance from water did not affect grazing patterns as much as range condition. Changes in range condition were slight due to low precipitation and time needed for plant response.

THE SANTA RITA GRAZING SYSTEM.

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The Santa Rita Grazing System is a 1-herd, 3-pasture, 3-year rotation now being pilot tested on the Santa Rita Experimental Range near Tucson, Arizona. The system is designed to meet the growth requirements of perennial bunchgrasses on semidesert grass-shrub ranges of the Southwestern United States and is the best of many rest-grazing schedules tested. This is an area where 90 percent of the year's forage is produced in the summer, 10 percent or less in the spring, and where herbage yields are strongly affected by growing conditions of the previous year. The rest-grazing sequence is: (a) rest 12 months (November-October), (b) graze 4 months (November-February), (c) rest 12 months (March-February), (d) graze 8 months (March-October). Each range is rested during both spring and summer growth periods two years out of three but each year's forage is utilized. A full year of rest prior to spring grazing provides old herbage to protect early spring growth from repeated close grazing. Benefits are expected to be greatest where animals naturally congregate, as around water.

EXPERIMENTS ON UTILIZATION AND CONSERVATION OF GRASSLANDS IN ICELAND.

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ciety of Iceland; and Scientific Adviser of UNDP/FAO. Agricultural Research Institute, 110 Reykjavik, Iceland.

Livestock production is the second main industry of Iceland. Extensive overgrazing has contributed to soil erosion which has resulted in the loss of half the vegetation present at the time of settlement 1,100 years ago, and in reduced fertility of what is left. To form the basis for an aggressive program of rangeland improvement and management, six 5-year grazing experiments were initiated in 1975. They included both separate and mixed grazing of growing cattle and ewes with lambs on different soil types and at different elevations. The main objectives are: (1) to find the optimum stocking rate or grazing capacity for the particular vegetation, (2) to determine the increase due to fertilization, and (3) to measure the effect of different grazing pressures on the vegetation.

The present paper deals only with results from three of these experiments. The two-year (1975 and 1976) preliminary results show that the performance of lambs is very good on dry highland, fairly good on dry lowland, and improves with fertilizer application; whereas the gain of lambs on drained lowland bog is extremely poor, both on fertilized and unfertilized pastures. The gain per hectare was greater on the bog than on the dryland pastures due to a higher grazing capacity. The results show that the grazing value of the rangelands generally is rather poor and that the vegetation of the lowland is of lower quality during the latter part of summer than that of the highlands.

CATTLE WEIGHT GAIN COMPARISONS UNDER SEASONLONG AND ROTATION GRAZING SYSTEMS.

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Calves were heavier and had a higher daily gain in 4 out of 6 years under seasonlong compared with a rotation system of grazing. Cows, however, gained slightly more in 4 out of 6 years under the rotation system. Differences were not statistically significant for either size of animal. Tests were made using a complex cross-over statistical design to minimize variation between range vegetation in the treatment areas. The study was conducted in the ponderosa pine bunchgrass type of the central Rocky Mountains of Colorado in an area that receives most of its moisture as summer rainfall.

BUSH CONTROL AND ASSOCIATED TSETSE FLY PROBLEMS OF RANGELAND DEVELOPMENT ON THE COASTAL PLAIN OF EAST AFRICA.

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Time lapse aerial photography was used to compare long term changes resulting from several levels of

cattle stocking and bush clearing on rangeland of the East African coastal plain. The study areas were located on a well developed commercial ranch situated along the coast of the Indian Ocean opposite the northern tip of the island of Zanzibar. Approximately 12,000 head of improved zebu cattle have been successfully grazing the 49,000 ha ranch for 2 decades. Recently, however, bush encroachment and tsetse flies have complicated ranch management despite aggressive programs in bush clearing and drug treatment against Trypanosomiasis. Part of the ranch is being used as a test site for an integrated project to control tsetse flies. This paper presents an assessment of successional changes in vegetation cover and describes the changes in relation to historic wildfire, present land use, and the occurrence of tsetse flies. Recommendations for balancing forage needs with bush control measures are provided.

MANAGING RANGELANDS FOR THE AMERICAN PRONGHORN ANTELOPE.

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The majority of the American pronghorn antelope coexist with domestic livestock in North America. Competition for forage or water is generally not a problem on ranges in good condition, but can be on ranges in deteriorated condition. Rangelands with the following characteristics are preferred ranges for both livestock and antelope: low rolling terrain vegetation predominately grass with forbs and browse abundant, and water available every 3 miles.

Antelope thrive best on rangelands with a diversity of vegetation, an abundance of grass-forbs-browse, plants with high succulence, and growth height from 12 to 24 inches. Vegetational type manipulation projects can be advantageous or deleterious to antelope depending on how they are planned and accomplished. Should a range not have the vegetational ground cover preferred by antelope and conversion could accomplish this objective, then the project could be beneficial. Single-species range seedings are not desirable.

Pronghorn densities are best on range where water is available every 3 to 4 miles. Antelope use man-made water developments such as reservoirs, troughs and water catchments.

Fences, which restrict antelope movement, can be detrimental. However, properly designed barbed wire fences provide a minimum restriction to movement. Woven wire fences are generally a barrier and, therefore, are not recommended on antelope ranges.

COMMERCIAL HORSE BREEDING AS A POTENTIAL ALTERNATIVE GRAZING USE OF SOUTH AUSTRALIAN ARID RANGELANDS.

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The suitability of Australian arid rangelands for extensive horse breeding is discussed, and the development of horse breeding as a livestock export is briefly

described and quantified in comparison to sheep and cattle production during the period 1890-1930.

The development and induced evolution of the Australian Waler horse type is described with performance data of these horses as mounts of the Desert Mounted Corps in Sinai during World War I.

The subsequent decline of Australian horse breeding during the period 1930-1960 is then traced to the point where emerging post war affluence in urban population centres, and agricultural prosperity, generated an intense demand for quality horses for pleasure, recreation and work.

The contemporaneous introduction of the American Quarter Horse to Australia is then discussed, and its effect in motivating establishment of the Australian Stock Horse Stud Book in 1970.

The modern Australian Stock Horse type is then described, and the bio-economic advantages of the species as a re-emerging grazing animal under the extensive Australian arid rangeland grazing system is discussed and assessed.

The paper demonstrates that horse breeding on Australian arid rangelands associated with sheep and cattle grazing has bio-economic potential, and optimises rangeland biomass use.

THE ECOLOGY OF THE ANNUAL MIGRATIONS OF CATTLE IN THE SAHEL.

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Many of the migrations of cattle in the Sahel are regulated by traditions determining where to go, the tracks to use, and the sequence of moving herds. Consequently, the availability and quality of food show a fixed pattern of annual variations for a given herd.

Especially after the recent drought, others than the traditional herdsmen started to interfere with the use of natural grasslands of the Sahel. To improve the use of the pastures it is necessary to analyse the original exploitation system.

This study is an attempt to analyze the "transhumance" between the Central Delta of the Niger (Mali) and the southeast of Mauretania. During a whole year the food preference of cattle is studied, the quality of the food is determined, and estimates are made of the quantity available. For one single herd of some hundreds of animals out of the hundred thousands in the region in question, both the demography and the condition of the cattle are observed in relation to the food situation. The composition and productivity of the vegetation are determined in relation to the exploitation intensity.

A GRAZING ECOSYSTEM IN WESTERN AFGHANISTAN.

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The Hamdamab in western Afghanistan is a discrete area of 2,400 sq.km that is used as winter pasture by nomads descending from the Hindu Kush. Village-based and semi-nomadic stock also use the area year round. Hamdamab was surveyed seasonally for its

human, livestock and plant population, the diets of the stock and the productivity of the vegetation. The vegetation was surveyed at 127 sites on a 5 km grid. Total plant density varied between 3 and 74 thousand/ha. *Artemisia herba-alba* and *Poa bulbosa* were the dominant species and, apart from a spring flush of ephemerals, livestock production depended on these two species. Fuel cutting of *A. herba-alba* denuded over 3 percent of the area per annum; but regeneration from seed was adequate provided the grazing pressure was not too high. Estimation of carrying capacity demonstrated that the area is over-stocked and that nomadic flocks require greater security of their grazing rights and control of grazing pressure. Nomadism is essential for the maintenance of these flocks but a secure winter base is recommended together with opportunities for investment, other than in livestock, to facilitate control of grazing pressure.

A COMPARISON OF BEEF GAIN POTENTIALS ON COOL SEMIARID AND SUBTROPICAL PINE FOREST RANGES.

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The visual aspects of the ponderosa pine (*Pinus ponderosa*) ranges in central Arizona and the longleaf-slash pine (*Pinus palustris*-*P. elliotii*) ranges in central Louisiana have some similarities. However, many characteristics of these two areas differ.

Ponderosa pine ranges experience cold snowy winters and limited moisture during the growing season. Longleaf-slash pine ranges experience the warm lower Coastal Plains subtropical climate where moisture is ample throughout the year.

The native herbaceous forage species under ponderosa pine are approximately balanced between warm- and cool-season species. Forage composition under longleaf pine is dominated by warm-season grasses. Fire plays a more significant role in the ecology of longleaf pine forests than in ponderosa pine forests.

Beef gain per acre by yearling cattle on native forage during the summer growing season appears to be somewhat higher on ponderosa pine range when no timber is present. However, an analysis of forage quantity and quality under forest stands suggests longleaf-slash pine ranges have a greater capacity to produce beef and trees together.

MANAGEMENT OF NATURAL GRASSLAND IN THE SYLVO-PASTORAL AREA OF NORTHERN SENEGAL.

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For the last 25 years, exploitation of natural grasslands in the Senegalese Ferlo area has become possible all year round through the establishment of permanent watering points.

General studies in the sandy part of this area have shown that natural vegetation had remained balanced in the new pastoral ecosystem while it had changed around watering points.

More detailed observations have been carried out in the last four years on three main types of pastures

at increasing distances from watering points. They have pointed out important variations in their density and botanical composition not only from one year to the other (incidence of rainfalls) but also in relation with the distance from these points (influence of stamping and organic matter deposits). The most important variations are related to: (1) the percentage of legumes, which decreases from the water points to about 2 or 3 km, then increases and remains constant whereas the pattern of grasses is quite the opposite; (2) the composition of grasses and legumes; (3) the production of dry matter, particularly, which is generally higher close to the watering points than 5 to 6 km further, and always lesser at a distance of 2 to 3 km, whereas the rate of crude protein is always highest at 0.5 km (i.e. 12 to 15 percent against 8 to 10 percent).

It can be considered that the sandy Ferlo natural grasslands, after management, have on the whole undergone few changes, with the exception of those due to rainfalls. It is only within a radius of 4 to 5 km from the watering points that substitution types of pastures of about equal quality and value have been installed. No degradation has been noted.

PATTERNS OF DEFOLIATION DURING CONTINUOUS AND ROTATIONAL GRAZING OF RANGELAND BY CATTLE.

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The patterns of defoliation under continuous and rotational grazing of an area containing a typical mixture of range types were monitored by means of repeated observations and measurements of marked tillers. The rotation consisted of 12-day grazing periods and 60-day rest periods. The same stocking intensity was applied in the two methods of management.

Grazing was selective with regard to range types, species within range types, and tiller type and height within species. Preferences changed at different times of the year, but the patterns of selection were similar in the two treatments. Frequencies of defoliation under continuous grazing were not as high as commonly assumed. The most selected species received four or more defoliations in 6 to 11 percent of tillers during summer and autumn. The rotation prevented four or more defoliations and resulted in a small decrease in tillers receiving three defoliations. The heights to which tillers were grazed differed between range types, species within types and periods of the year, but were very similar under the two treatments.

It is concluded that continuous grazing of such range types at moderate stocking rates would result in insidious deterioration and that this could be prevented by rotational grazing.

RANGELAND VEGETATION OF THE TEXAS ROLLING PLAINS: RESPONSE TO GRAZING MANAGEMENT AND WEATHER.

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A study was conducted on 1420 ha of rangeland in Throckmorton County, Texas from 1960 to 1976, to evalu-

ate the response of native vegetation under continuous grazing at two levels of stocking, Merrill grazing system (4-pasture-3-herd; 12 months grazing, 4 months rest on each pasture), and complete exclusion of grazing. Frequency and relative frequency data were evaluated by species on an annual basis. During 1970 and 1972, standing crop (weight and species composition) was evaluated using a quadrat technique. Two species, buffalograss (*Buchloe dactyloides*) and Texas wintergrass (*Stipa leucotricha*) comprised 64 to 77 percent of the total herbage. Sideoats grama (*Bouteloua curtipendula*) and perennial threeawns (*Aristida* sp.) collectively contributed an additional 6 to 10 percent, while forbs generally contributed less than 10 percent. Based on the variables evaluated buffalograss frequency remained stable under heavy yearlong grazing while Texas wintergrass declined. Buffalograss declined under the lighter stocking rates with only a trace remaining in the grazing enclosure at the end of the study. Texas wintergrass increased under light stocking. Neither frequency nor relative frequency of sideoats grama were affected by grazing treatments. However, standing crop was significantly reduced at the higher stocking rate. Frequency of perennial threeawns did not respond to grazing or climatic fluctuations. Both frequency and weight of annual forbs increased significantly on grazed pastures in years following above average fall and winter rainfall. However, this did not occur in the enclosures. Perennial forbs were stable under all treatments, but were lowest under the heavy stocking rate. Vegetation changes under the heavy stocking rate reflected a decline in vigor but little change in frequency of the dominant species. Vegetation response was similar under continuous grazing and the Merrill grazing system under the same stocking rate. Trends of vegetation in the ungrazed enclosure differed significantly from the grazed pastures.

THE IMPACT OF SHEEP GRAZING ON LONG-TERM SUCCESSIONAL TRENDS IN SALT DESERT SHRUB VEGETATION OF SOUTHWESTERN UTAH.

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Since 1935 the USDA Forest Service has conducted a sheep grazing experiment on winter rangeland at the Desert Experimental Range, Utah. The treatments comprise three intensities of grazing pressure, and either autumn, winter or late winter grazing periods. Permanent plots in grazed paddocks and fenced enclosure were charted on four occasions over the next forty years. From an initial value of 4 percent in 1935, the cover of perennials in vegetation protected from grazing has increased steadily to more than 10 percent in 1975, with no indication of approaching climax conditions. Matching grazed plots have an average of 8 percent perennial cover. Grazing at any intensity or any part of the winter season did not affect the general trend in plant cover or species composition, but did in some cases modify the magnitude of change. Under both grazed and protected conditions: (1) the least palatable shrub, *Atriplex confertifolia*, exhibited a short-term rise in total cover followed by a steady decline; (2) the more palatable co-dominant shrub, *Ceratoides lanata*, consistently increased in cover; (3) the three principal perennial grasses more than trebled their cover. These trends contradict accepted range longevity, juvenile plant establishment and differential response to climatic stress.

GRAZING AS A MANAGEMENT TOOL IN CONSERVATION (A DUTCH APPROACH).

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The landscape in the Netherlands has developed under the influence of human activities during many centuries. Old farming practises increased the ecological variety due to the constant transport of nutritious matter from a wide surrounding to the agricultural fields near the residences; thus giving rise to many local gradual transitions of trophic levels of the soil, creating a wide range of ecological niches for a diversified vegetation development. Modern farming practises of the 20th century are levelling this variety due to the use of fertilizers and advanced draining techniques.

It is in the interest of nature conservation to preserve parts of the man-made landscape in the former way. Generally spoken this can be done by applying the old farming practises which is however a rather expensive method nowadays. Permanent grazing at very low stocking rates presents an alternative method with good results for this purpose.

Cows, horses, sheep and goats are used at different places. The impact of cattle behaviour on the system in the sense of doing the same things at the same places with the same intensity every year can be compared with the impact of old farming practises. Gradually in time decreasing stocking rates lead to a higher biological variety of the area as well in vegetation structure as in plant and animal diversity

NITROGEN FERTILIZATION AND LIVESTOCK GRAZING ON BLUE GRAMA RANGELAND.

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The impact of rangeland fertilization (45 kg N/ha) on herbage production, species composition, forage availability, diet selectivity, chemical composition and animal gain has been compared to unfertilized range since 1968. Both pastures contain upland, hillside and bottomland range sites. Fertilization has increased herbage production from 1,098 kg/ha to 2,054 kg/ha. Bottomland range sites have shown the greatest response

with a 1300 kg/ha increase. No changes in species composition were noted from fertilization until the drought of 1971. Drought conditions were accentuated with fertilization; but fertilized pastures recovered more rapidly following drought. After the drought major shifts in species composition occurred as blue grama (*Bouteloua gracilis*) declined 66 percent while sand dropseed (*Sporobolus cryptandrus*) increased 25 percent. Only in drought years did undesirable plants increase. The increase was slightly more pronounced with fertilization. Animal performance was consistently higher from fertilized rangeland. Stocking rates were twice as great under fertilization treatments with steer gains approximately 10 percent higher per animal. Steers grazing fertilized range gained an average of 45 kg/ha while those on unfertilized range gained only 21 kg/ha. Animal diets from fertilized rangeland exhibited a greater diversity of plant species with a higher protein content. Protein supplement for livestock was reduced approximately 50 percent through fertilization. Results indicate range fertilization was beneficial on all sites, but current cost of fertilizer will dictate the acceptability of the practice

CATTLE AND VEGETATION RESPONSES TO MANAGEMENT OF MEDITERRANEAN RANGELAND IN ISRAEL.

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A grazing trial with beef cattle of mixed European breeds was conducted on herbaceous Mediterranean foothill range in the north of Israel. The treatments included continuous and rotational, heavy and moderate grazing. After ten years, the rotational heavy and continuous heavy grazing treatments were switched. Trends that had been observed at the beginning of the trial appeared again: rotational grazing encouraged the growth of grasses and reduced the cover of forbs; residual litter at the end of the grazing season was greater under rotational grazing than under continuous. However, animal production was greater under continuous grazing, and more so after the switch-over than previously. This may indicate that animal response to rotational grazing is less favorable when grass cover is initially lower and forb cover higher. During the last year of the switch-over, suckling cows with calves were used instead of dry cows as previously. As a result, pasture productivity increased considerably even though the number of suckling cows was reduced relatively to the dry cows in order to maintain an equivalent number of animal units.

Section 9. Rangeland Resource Improvement

METHODS AND TECHNIQUES FOR THE REPLACEMENT OF NATIVE GRASSLANDS IN SOUTH AFRICA BY LOW COST TECHNIQUES.

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Much of the native grassland in South Africa is of low carrying capacity and has a grazing period confined to the summer months. The principal reasons for this are that the soils are generally acid and infertile while the winters are dry and cold.

In recent years ways and means of improving the carrying capacity of these grasslands have been examined, evaluated and are now being put into practice by farmers. This has been achieved by the application of one or more or a combination of the following techniques. (1) The fortification of natural grasslands with legumes by direct drilling over banded superphosphate, lime and if necessary a trace element mixture. This is done in a single one pass operation with a sodseeder specially designed for the purpose. (2) The fertilisation of natural grasslands with N and P followed by programmed stocking and management and oversowing with improved temperate grasses. These treatments result in the development of a high potential pasture that can then be fortified with legumes as described above. Local limitations that necessitate the use of these techniques in the development of highly productive pastures, as well as the results achieved, are discussed.

LONG-TERM SOIL CHANGES ASSOCIATED WITH SEEDED STANDS OF CRESTED WHEATGRASS IN SOUTHEASTERN ALBERTA, CANADA.

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The only sizeable pasture potential in Canada is represented by about 9 million hectares of rangeland and submarginal cropland that agriculturists believe should be converted to seeded grass-legume mixtures. It is estimated that a 3- to 5-fold increase in production would result. However, environmentalists are disturbed at the suggested destruction of nearly one half the remaining native prairie of the region and the creation of an unstable mono-culture in its place. Nor do environmentalists believe that the 3- to 5-fold yield increase will be long-lasting. In southern Alberta, we have studied 40- to 49-year-old stands of crested wheatgrass and adjoining Mixed Prairie range. In those years for which yield data are available, crested wheatgrass consistently outyielded the grass and sedge component of range vegetation by ratio that ranged from 1.08 to 12.42. Analysis of vegetation showed that crested wheatgrass has remained a mono-

culture and had not been invaded by species native to the region. Analysis of soils showed that exhaustion of N was not a factor in persistence of crested wheatgrass stands. Bulk densities tended to be higher under crested wheatgrass than under native range but pH of the soil was slightly less. Water soluble aggregates in the Ah horizon were higher under native range than under crested wheatgrass as was $C_6H_6/EtOH$ -soluble C. Additional work will be done on total C, carbohydrates, and on characteristics of organic matter in terms of phenol groups. Our results indicate that, in the study area, seeded stands of crested wheatgrass became a permanent part of the vegetation and yield was dependent mainly on current rainfall. Soil profile differences will be discussed with the agriculturists-environmentalist controversy in mind.

ESTABLISHMENT OF RUSSIAN WILDRYE (*ELYMUS JUNCEUS* FISCH.) IN STRIP-TILLED *STIPA-BOUTELOU* PRAIRIE.

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The grazing productivity of areas that had been cultivated or rangeland in poor condition may be increased through renovation and seeding of introduced forage crops. Such stands of introduced forages, when used as complementary pastures, have increased livestock gains by three to six times that of native range. However, loss of forage production from nonuse during renovation, high renovation costs, and risks of soil erosion and stand failure make the economics of renovation questionable. Strip renovation, seeding the introduced forage species into tilled strips and leaving the intervening strips in native range until the introduced species is well established, has the potential of allowing some forage utilization during stand establishment. Tests conducted at the Manyberries Research Substation on *Stipa-Boutelou* prairie in southeastern Alberta showed that Russian wildrye established best on the widest strips (15-120 cm). Total forage production on the strip-tilled plots over the first 5 years was about twice that on untreated native range and about equal to the production on completely tilled plots. Subsequent tillage of the native range strips increased growth of Russian wildrye but the total production over a 7-year period was greatest on plots that were completely tilled initially. Cattle avoided grazing the untilled native range strips and preferred the rows of Russian wildrye.

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GRASS ESTABLISHMENT ON LOWER SNAKE RIVER RANGELANDS.

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Laboratory and field studies were conducted in eastern Oregon and Washington to determine germination and establishment of native and introduced range species. Species were selected on the basis of their value to enhance and increase productivity of native range lands of the Lower Snake River. These lands have been heavily used by domestic and wild animals. Using various seed treatments and reducing the exposure time of broadcast seed to native and introduced bird predation appeared to be a successful and practical means of enhancing problem range sites. In addition, mat-type materials were used in the field resulting in unusual problems but showing promise for soil stability on disturbed sites.

RANGE IMPROVEMENT PRACTICES IN IRAN.

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Lack of adequate attention to sound range management principles is a major factor influencing loss of desirable vegetal cover and topsoil. This practice has caused the ruin of extensive rangeland areas and soil.

In order to prevent soil erosion, rehabilitate depleted rangelands, increase desirable vegetal cover and forage production, the Government of Iran has initiated different improvement practices all over the country. Application of the improvement measures has expanded rapidly within the past 6 years. Through planting of shrubs, seeding of grasses and forbs, water conservation practices and protection, 3.5 million hectares of rangeland have been improved.

The work carried out shows that rangeland potentials are much higher than one could imagine looking at the depleted non-protected areas. The results attained clearly show that range productivity can be increased many fold.

A number of experiments carried out show that re-seeding is very difficult and not economically feasible wherever average rainfall is less than 300 mm. Re-seeding is technically and economically justified wherever precipitation is greater than 300 mm and soil conditions are favorable. Twenty two thousand hectares of range reseeded have been carried out to date in Iran.

Along with water conservation measures, shrub species, mainly *Atriplex* species, have been transplanted in areas receiving 100 to 300 mm rainfall annually. To date 45000 hectares of rangelands have been improved by transplanting. Areas receiving less than 100 mm rainfall annually, which are mainly sand dune or salt deserts, are protected and some part of it transplanted using mainly *Haloxylon* sp.

EFFECTS OF GRAZING, CLIMATE, FIRE, AND OTHER DISTURBANCES ON LONG-TERM PRODUCTIVITY OF SAGEBRUSH-GRASS RANGES.

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Productivity has been restored to millions of hectares of western ranges through seeding of crested wheatgrass over the past 40 years. Millions of additional hectares are in need of improvement. Controversy exists over continued use of crested wheatgrass in preference to native species in rehabilitation programs.

Long-term research in Utah has provided information on the productivity potential of both crested wheatgrass and native species; and grazing management studies show type of management needed to maintain their productivity.

Increased grazing capacity on ranges seeded to crested wheatgrass allowed rest from grazing in adjacent depleted native range, which, together with brush control treatment, restored productivity to native range. Because crested wheatgrass is superior to native grasses for early spring grazing whereas native grasses are superior for late summer and fall grazing, both can be used advantageously in grazing management programs.

Brush invasion poses a problem to productivity of both crested wheatgrass and native grasses. The effects of heavy grazing on brush invasion were dwarfed by effects of climate, indicating that periodic brush control is necessary. Fire is a cheap and effective method of brush control, but on severely depleted range, treatment with herbicides reduced sagebrush and increased grass, which contributed to effectiveness of fire several years later.

INTERSEEDING OF NATIVE MIXED PRAIRIE IN THE GREAT PLAINS.

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The native mixed grass prairies in the Great Plains of the United States have been supporting grazing animals for thousands of years. While most of the higher producing land has been destroyed by the plow, many thousands of acres of native prairie remain. Much of this vegetation remains only because of its inability to be revegetated by standard "farming" practices. Because of the dwindling amount of native range and remaining and the declining production of those areas that have been overused, we need an improvement technique for increasing forage quantity and quality of native ranges. Interseeding is one range improvement technique that has accomplished these objectives.

A study by North Dakota State University has shown that interseeding of Travois alfalfa (*Medicago sativa* L.) into native mixed prairie increased production 32 percent. This data along with other studies conducted in the Great Plains have shown high degrees of success as well as significantly improved production from interseeding ecologically adapted grasses and legumes into native range.

B

ESTABLISHMENT OF CHENOPOD SHRUBS BY TYNE PITTING ON HARDPAN SOILS IN WESTERN NEW SOUTH WALES, AUSTRALIA.

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Chenopod shrubs provide livestock with valuable drought forage and protect the soil over extensive areas of New South Wales. In the White Cliffs region, which has an average annual rainfall of 230 mm, these low shrublands are generally broken by bare and unproductive hardpan soils. In trials conducted over 4 years, a tyne pitter was used to establish the native chenopod shrubs, oldman saltbush (*Atriplex nummularia*), perennial saltbush (*Atriplex vesicaria*), yanga bush (*Maireana brevifolia*) and black bluebush (*Maireana pyramidata*) on these soils under conservation stocking. Shrubs were established on an average of 64 percent of the sown pits. Seasonal conditions strongly influenced the growth of the species sown. Oldman saltbush was more tolerant of prolonged flooding of the pits caused by above average rainfall than either perennial saltbush or black bluebush, but was also more adversely affected by subsequent hot dry conditions than these two species. Results suggest that perennial saltbush and blackbush are the most persistent shrubs in average rainfall years. All species, except black bluebush, set seed, which collected in the pits. The number of yanga bushes increased due to germination of this seed. Sheep and kangaroos grazed all species but preferred oldman saltbush. Further work is required to evaluate the persistence of sown species.

CONTOUR FURROWS SEEDED WITH GRASSES AND LEGUMES INCREASE PRODUCTION ON SEMIARID RANGE SITES.

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In arid and semiarid climates, inadequate soil water, especially during germination and seedling development, restricts establishment of productive stands of grasses and legumes. Water deficits are further compounded on fine-textured sites subject to water loss from runoff. In the northern Great Plains, contour furrowing, a practice that has been used primarily to reduce runoff, erosion, and increase production on fine-textured rangelands, effectively enhances the soil water environment and subsequent establishment of seeded grasses and legumes on sites where seeding and interseeding are not normally feasible because of inadequate soil water. On a fine-textured range site in Eastern Montana, establishment of such species as Russian wildrye (*Elymus junceus*), crested wheatgrass (*Agropyron cristatum*) and alfalfa (*Medicago sativa*) in contour furrows increased average annual productivity 130 to 260 percent (up to 1400 kg/ha). On a coarser-textured range site, alfalfa seeded into contour furrows increased average annual forage production by 152 percent (906 kg/ha) and beef production by 102 percent (26 kg/ha). Increased snow trapping and reduced snowmelt and rainfall runoff on contour furrowed treatments increase overwinter recharge and seasonal soil water availability. The enhanced soil water regime

benefits production of the interfurrow native species as well as the establishment and production of the grasses and/or legumes seeded into the furrows.

THINNING BLUE GRAMA RANGE FOR INCREASED SEED AND FORAGE PRODUCTION.

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Chemical thinning of shortgrass rangeland is a new technique for increasing seed production and forage availability. Native blue grama range was thinned in strips with glyphosate to one third of the original stand. Thinning increased the growing space per plant which increased height of seedstalks and size of seedheads. One year after the thinning treatment, during a year of acute drought, the number of seedstalks was 375 percent greater and the yield of seed was 525 percent greater on the thinned rangeland than on the untreated. The thinned stand produced more total herbage than the untreated grass stand, and because thinning produced taller plants with a more upright growth form, the forage produced was also more readily eaten by the livestock. The results of this study indicate that the concept of the "open community," where the available soil moisture is utilized by a smaller number of plants, increases water use efficiency. This concept also increases the potential for higher seed yield for local sources of native grass seed and offers a new management technique for increasing the availability of the herbage to the livestock.

SOIL APPLIED HERBICIDES FOR BRUSH CONTROL IN SOUTHWESTERN UNITED STATES AND NORTHEAST BRAZIL.

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Unwanted woody plants constitute the most serious management problem confronting land management personnel in the Southwestern United States and Northeast Brazil. Many species in each country can be controlled with herbicides; however, economic parameters and the presence of adjacent susceptible crops limit the application of broadcast herbicides in many situations. Pelleted and granular herbicidal formulations have considerable utility on rangeland of both countries. Picloram, tebuthiuron, karbutilate and dicamba have been evaluated against the most important species in Southern Arizona, both as broadcast and individual plant treatments. Picloram is effective against most species of *Acacia* when applied immediately prior to or during the rainy season. Tebuthiuron is effective in controlling velvet mesquite, catclaw acacia, wait-a-minutebush and creosotebush. Karbutilate is effective in controlling velvet mesquite and dicamba is effective for the control of creosotebush. Pelleted and

granular herbicides have a number of advantages over broadcast herbicides for brush control in Northeast Brazil. Results in Brazil indicate that transfer of weed and brush control technology between the two countries is possible with a minimum of developmental research.

ADVANTAGES OF HERBICIDES FOR BRUSH CONTROL ON NEWLY SEEDED RANGELAND IN WESTERN CANADA.

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Mixtures of 2,4-D with picloram, dicamba, or 2,4,5-T were evaluated for control of aspen poplar (*Populus tremuloides* Michx.) on newly seeded rangeland. Also, changes in forage yields and in the composition of forbs were documented following herbicide treatments.

Aspen poplar reproduces from creeping roots to become the dominant species on rangeland seeded to bromegrass and alfalfa. Alfalfa yields were 5 to 10 fold greater in openings between than directly under aspen poplar suggesting that the legume is easily eliminated. However, mixtures of 2,4-D with the above herbicides gave satisfactory weed control but eliminated alfalfa. A vegetation analysis of forb data revealed that picloram treated areas were species poor. Forage yields were greater on areas treated with herbicide mixtures than on non-treated areas. When fertilizer was used with herbicides, forage yields were increased over non-fertilized areas but the number of forbs present was similar. The main difference among herbicides tested with and without fertilizer was the reduction in forbs on picloram-treated plots, which provided a diet for cattle of mainly grasses.

RANGELAND BRUSH AND WEED CONTROL WITH TEBUTHIURON.

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Tebuthiuron (N-(5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl)-N, N'-dimethylurea) (trade named SPIRE) in aerially applied pelleted formulations has demonstrated excellent control of many widespread brush and weed species on rangelands of southwestern United States. Problem woody species of this region are predominately of the genera *Prosopis*, *Acacia*, *Quercus*, *Aloysia*, *Larrea* and *Opuntia*, which form complexes with many other locally abundant species presenting formidable range improvement problems.

Tebuthiuron in 3 mm, 20 percent extruded pellets was applied at 0.56 - 4.48 k/ha at a number of locations beginning in 1974 by Eli Lilly and Company plant scientists. *Larrea divaricata* and *Flourensia cernua* were controlled at 0.56 - 1.12 k/ha. *Aloysia lycoides*, *Cercis pinnata*, *Citrus periantheri*, *Acacia berlandieri* and *Condalia* species were controlled at 1.12 to 2.24 k/ha. *Acacia farnesiana*, *A. rigidula*, *A. greggii* and *Colubrina texensis* were controlled at 2.24-4.48 k/ha. *Quercus stellata*, *Q. marilandica*, *Ilex vomitoria* and *Ulmus alata* were controlled at 1.68 - 3.36 k/ha. Broadleaf weeds were effectively controlled at rates above 1.12 k/ha. Results indicate that initial damage to grasses can be minimized by dormant season applications from December to March, which also

derives maximum efficacy from spring rains. No detrimental shifts in botanical composition of grasses has occurred on treated areas. Forage production has generally exceeded that of the control one year after treatment.

BRUSH CONTROL WITH LOW VOLUME-LOW PRESSURE AERIAL APPLICATION.

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In August of 1975 an aerial brush control research test was established in the semitropical Huasteca Area of Mexico. This area consists of approximately 150,000 hectares on the coast of the Gulf of Mexico. The main brush problem is regrowth huisache (*Acacia farnesiana*). Application of herbicides by air is the only feasible method of controlling this reinvasion of huisache without damaging the excellent stands of introduced grasses such as guinea grass (*Panicum maximum*).

The standard commercial treatment of TORDON* 101 + ESTERON* 245 was compared to TORDON 225 and other experimental herbicides. Experimental products included were M-3990 (U.S. and Mexico formulations), and Dowco* 233 as M-3724 alone and in combination with picloram amine (0.12 kg/l formulated in Mexico). Chemicals were applied in water alone and/or as diesel oil water emulsions in total volume of 10, 18, and 40 l/ha.

An evaluation made 10 months after application indicated that the best root kills of huisache were obtained with following treatments: Dowco* 233 (M-3724) @ 0.56 kg a.i./ha + picloram amine @ 0.60 kg a.i./ha in water plus surfactant with 80.4 percent and the M-3990 U.S. and Mexico formulations @ 1.12 kg a.i./ha as diesel oil-water emulsions with 79.5 percent respectively. These treatments were applied in a total volume of 40 l/ha, which gave slightly better plant kills (approximately 8 percent) than the lower volumes. (*Trade marks of the Dow Chemical Company).

BIOLOGICAL CONTROL OF DIFFUSE AND SPOTTED KNAPWEED BY UROPHORA AFFINIS AND U. QUADRIFASCIATA IN BRITISH COLUMBIA.

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Centaurea diffusa Lam. and *C. maculosa* Lam. (diffuse and spotted knapweed, respectively) have invaded an estimated 30,000 hectares of range in British Columbia, and threaten an additional 1.1 million hectares. In an effort to stop the spread of knapweed, two seed-destroying insects, *Urophora affinis* Frfld. and *U. quadrifasciata* Frfld. (Diptera: Trypetidae), were introduced by Canada Agriculture in 1970 and 1971 on separate stands of diffuse and spotted knapweed. From initial releases of a few hundred "gall flies", population sizes on the release sites have reached the millions. An intensive study was carried out to evaluate the effectiveness of the biocontrol agents, and to predict the outcome of the insect/plant system. Viable seed numbers were reduced as much as 75 percent of potential seed production on the release sites.

Knapweed suffered a change in flowering pattern, an increase in bud abortion, and incomplete flowering of seed heads. However, from seedling survival studies, it was concluded that enough seed is being produced, at present levels of attack by the gall flies, to maintain existing weed densities on the release sites. Therefore, it is predicted that *Urophora* spp., alone, will not successfully control knapweed in British Columbia.

EFFECTS OF BUSH CLEARING ON GRASSLANDS IN BOTSWANA.

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Bush clearing as a means of improving range condition has been assessed in Botswana since 1974. On 5 sites representative of the major vegetation zones, 100 hectare sites were selected. Half of each site was cleared of bush and half left untouched with the object of determining the effect of bush removal on yield of grass dry matter, botanical composition of the lower herbage layer and the effect on the microclimatic conditions. The method of clearing was to cut the bushes approximately 30 cm above the ground with axes or power saws and to paint the cut stumps immediately with a mixture of TORDON 155 and diesel oil in the ratio of 1 to 3. The sites were grazed for one week and rested for five weeks throughout the year. There was a significant difference in yields of dry matter between sites, years, cleared and uncleared, and between grazed and protected areas. On 4 sites there was evidence that clearing had a beneficial effect on the botanical composition. Bushes reduced radiation falling on the grass layer by more than 50 percent and reduced the air temperatures at midday by 2-3 C. Provided there was a good grass cover, bushes had little effect on soil temperatures. Under bushes the soil tended to dry out faster at depth than at the surface, while the opposite was the case where bushes were removed.

IMPLICATIONS OF FERTILIZERS IN PLANT COMMUNITY DYNAMICS OF NORTHERN GREAT PLAINS RANGELANDS.

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Fertilization of native and seeded rangelands to improve forage quality and quantity is now a widely accepted practice throughout North America and elsewhere. In the Northern Great Plains the potential for increase in forage production and subsequent red meat production has only been partially realized. One of the major reasons for not achieving the full benefits of fertilization is a serious lack of adequate management techniques, which require a level of intensity not now inherent in rangeland management systems. Increasing forage production alone is not the major objective of fertilization. Rather, the change in plant community successional stages to coincide with the desired grazing scheme is most desirable. In order to effectively manipulate communities to fit the desired status it requires an in-depth knowledge of the soil-plant-animal system. Studies at the Dickinson Experiment Station, employing a dozen different fertilizer treatments, are presently elucidating some of the parameters of plant community changes, soil nutrient

cycling, soil moisture use efficiency, protein content of selected species and forage production to allow the integration and monitoring of intensive grazing management as the final step in the use of fertilizer as a management tool.

RENOVATION OF ABUSED GRAZING LANDS IN THE NORTHERN GREAT PLAINS USING NITROGEN FERTILIZER.

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A native pasture that had been overgrazed for 50 years was divided into separate pastures, which were fertilized with 45 kg N/ha (45-N) annually, 175-N each fourth year, or 0-N, and all grazed with yearling steers. One additional pasture was neither fertilized nor grazed. Forage and beef production the year prior to fertilizer application were near 2000 kg/ha and 73 kg/ha, respectively. During the 10th year, forage and beef production were 4950 kg/ha and 139 kg/ha, respectively, on the pasture receiving 45-N annually; 3400 kg/ha and 126 kg/ha, respectively, on the pasture receiving 175-N each fourth year; and less than 900 kg/ha and 86 kg/ha, respectively, where no fertilizer had been applied. Vegetative composition was changed from bluegrama, upland sedge and fringed sage to western wheatgrass, bluegrama, needlegrasses, and upland sedges. Stocking rate increased from .935 ha/steer where fertilizer was applied and the grazing season was extended from 90 to 135 days. The proper use of nitrogen fertilizer on abused grazing lands in the Northern Great Plains is effective in improving vegetative composition and increasing forage production, which improves animal performance.

NITROGEN AND SULFUR IMPACTS ON THE COLD DESERT BIOME.

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Different forms of N at various rates, times, frequencies, and with and without sulfur have been applied to native and improved sites. Vegetation and edaphic responses have been measured over the past 25 years to define the role of N & S, explore their potential, and evaluate their worth.

Nitrogen at low levels significantly increased yield of crested wheatgrass on seeded range and of weedy annual plants on native range. Ammonium nitrate and urea forms were equally effective whether applied in the fall, winter or early spring. Sulfur with N at some locations and in cool springs caused an additional production increase. In wet summers, fertilization increased the number of sagebrush seedlings established but these gains were offset by increased mortality of young established plants on fertilized plots in succeeding years. Fertilized grasses depleted soil moisture more rapidly and accumulation of NO₃-N in the soil at low levels of fertilization was not excessive.

Nitrogen fertilization of the native sagebrush-bunchgrass range is not recommended. Fertilization of

crested wheatgrass stands with N and S may yield economic grazing returns under particular circumstances, but intensive management would be required to ensure sustained stand productivity under a spring grazing program.

TALLGRASS PRAIRIE RESPONSES TO ATRAZINE WITH 2,4-D AND FERTILIZER.

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This study was to determine the effects of atrazine, with and without fertilizer and 2,4-D on tallgrass prairie species. Good condition, tallgrass prairie vegetation on a loamy prairie range site in North-central Oklahoma was treated with atrazine, fertilizer and 2,4-D combinations in June of 1975 and 1976. Drought prevailed during the two years of this study. The application of atrazine alone and in combination with 2,4-D and fertilizer was successful in increasing tallgrass production while reducing annual grass and forb production. Much of this increase may be due to a decrease in interspecific competition. Indiangrass and switchgrass became codominants on the atrazine treated plots. In the second year, tallgrass production was increased by residual effects and increased further by a second-year application of atrazine with fertilizer. These results indicate that atrazine has a great effect on species response to intra- and inter-specific competition for soil water, nutrients and possibly sunlight.

FIRE IN THE MANAGEMENT OF HUMID GRASSLANDS IN SOUTH AFRICA.

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Fire and grazing have played a major role in the evolution of the high rainfall grasslands of South Africa. In their absence the grass plants become moribund and die and woody vegetation invades. Fire has therefore been retained as a management tool in grazing programmes to remove ungrazed top hamper. It must, however, be correctly integrated into the grazing programme and relate to the condition of the veld at any time. Where veld is dominated by grass species that soon become fibrous and unacceptable to animals, but which must be grazed if the area is to provide any feed for livestock, burning may be necessary each spring to remove the ungrazed material and stimulate new growth. However, where veld is dominated by species that retain their acceptability, it may be advisable to eliminate fire and allow those less acceptable species present to become moribund and die. Generally, however, fire may still be necessary in such veld if too much top hamper accumulates when it should be used as late as possible in the dormant season but before it is grazed, or the carrying capacity may be reduced by up to 60 percent in the short term, while sward degeneration may result in the long term through the invasion of less acceptable weed species.

PRESCRIBED BURNING OF RANGE ECOSYSTEMS IN SOUTH DAKOTA.

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Prescribed burning was conducted on Mixed Prairie in western South Dakota in the early 1970's. The purpose was to determine if native range, invaded by the winter annual Japanese brome (*Bromus japonicus*), could be improved. Burning reduced the density and yield of that species. Not anticipated was an increase in density and yield of western wheatgrass (*Agropyron smithii*) following late winter and early spring burning. This perennial decreaser is a dominant on most clayey uplands in the area. However, it becomes weakened when Japanese brome invades the site, with the result that grazing capacity is decreased.

Prescribed burning has a potential as an improvement practice when ranges become densely populated with Japanese brome. Grazing management is critical on burned areas because the regrowth vegetation is highly attractive to grazing animals.

USE OF FIRE TO MANAGE RANGELANDS OF THE GREAT PLAINS: NORTHERN GREAT PLAINS AND ADJACENT FORESTS.

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This paper deals with the historical role of fire in the Northern Great Plains and adjacent forests. Burning is now considered a promising method of range improvement. It is particularly useful in areas of higher precipitation where brush encroachment on grassland has been severe since white settlement.

Prescribed burning can be used to kill trees and shrubs especially when used with herbicides, to control certain undesirable herbaceous plants, to remove herbaceous litter promoting more uniform animal distribution, to stimulate growth of palatable woody suckers, and to create a seedbed for the establishment of forages. It is not recommended for general use on arid northern mixed prairie rangelands because of the detrimental effects on forage yield and soil moisture status. The effect of fire on grass, shrub and forested ranges is presented and related to season burned, fuel weights, fire temperatures, and vegetation. The use of fire to set back forest succession is presented and related to the range requirements of certain wild ungulates and livestock. Consideration is given to the interaction of fire, tree and shrub mortality, forage establishment, regrowth of woody suckers and grazing pressure.

Prescription procedures are presented for burning of grass, shrub and forested rangeland. The effect of weather conditions on success and safety are discussed.

USE OF FIRE TO MANAGE GRASSLANDS OF THE GREAT PLAINS: CENTRAL AND SOUTHERN GREAT PLAINS.

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This paper deals with the historical role of fire in the Central and Southern Great Plains and where we can use fire as an effective management tool today. Burning is usually recommended during "wet" years, but in some cases burning during "dry" years has the best long-term effect.

Prescribed burning is recommended to reduce large litter accumulations which suppress yields, to increase the palatability of coarse grasses, to control cactus species, to burn down dead mesquite, to clean up chained debris, to thin and suppress undesirable shrubs and forbs, and to remove dead juniper and young juniper trees. It is not recommended as a tool to control shrubs or increase grass production on short-grass ranges. The interactions between fire, competition, rodents and rabbits, and drought on the survival of sprouting shrubs are discussed. Impacts and benefits on wildlife as well as domestic livestock are mentioned.

Prescriptions for prescribed burning are presented, encompassing the complete range of fire behavior for low-volatile and high-volatile fuels. Several prescriptions to achieve specific effects on living shrubs, plant yields, and debris are presented.

NITROGEN LEVELS OF SOIL AND VEGETATION IN THE UPPER SONORAN DESERT AS AFFECTED BY FIRE.

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Measurements of nitrogen levels in soil and vegetation were taken during the second winter growing season following a 1974 wild fire of 105 ha, near Mesa, Arizona. Sampling was conducted on east and west exposure slopes on both burned and adjacent non-burned sites.

Soil nitrogen levels were significantly reduced on the west slope, and unchanged on the east exposure slope following fire. Percent nitrogen content of forbs and annual grasses were significantly higher on non-burned areas. The nitrogen content of composite groupings of selected shrub species was not significantly different between study areas. Total amounts of nitrogen (kg/ha) contained in forbs, were not affected by fire, while amounts of nitrogen in grasses and composite shrub groups were significantly greater on the non-burned site.

Results suggest that fire may contribute to reduced amounts of available nitrogen in the soil plus a decline in quality of available forage on upper Sonora desert rangeland.

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REESTABLISHMENT OF GRASSES ON LAND DISTURBED BY MINING IN THE NORTHERN GREAT PLAINS.

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Most land disturbed by mining in the Northern Plains will be returned to grass, creating a need to develop technology to insure successful re-establishment of desired species. Spoils vary widely in physical and chemical properties (especially texture, sodium content, and salinity level), but most are located in regions where severe water deficits occur during the growing season. Direct seeding into raw spoils, especially if high in exchangeable sodium or total salts, is usually unsatisfactory regardless of species, even when organic mulches are applied. As little as 5 cm of surface soil applied over sodic spoils vastly improves establishment and survival of adapted species, but approximately 75 cm is needed to restore full production. Adding water during periods of water stress essentially insures establishment, and makes seeding in any month during the growing season possible. Native species (*Agropyron*, *Stipa*, *Bouteloua*) can be introduced by direct seeding, in prairie hay, or possibly by sodding or sprigging, hastening natural succession. Cool-season species are easiest established. Better management (species selection, fertilization, grazing, ect.) may be needed for mined than for unmined land to maintain production. Long-term evaluations of vegetative stability are required.

REHABILITATION OF DISTURBED ALPINE RANGELAND.

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The increasing demand for minerals and energy resources is rapidly encroaching upon key alpine tundra ranges and watersheds in North America. Disturbance resulting from mining, mineral exploration, roads, recreation, and other activities often result in the total destruction of the topsoil and surface organic mat of alpine tundra ecosystems. The alpine environment is relatively severe with short growing seasons, low summer temperatures, high solar radiation loads, variable high winds, and congluturbation processes. These factors, together with the loss of topsoil and the exposure of rocky, infertile and often highly acidic parent materials resulting from mining and other disturbances, prolong rates of natural recovery into decades or even centuries.

A comprehensive program to develop rehabilitation techniques for alpine disturbances has been implemented on a broad scale on the Beartooth Plateau in Montana. This program is being supplemented by basic research on plant physiology, hydrology, plant succession, soils, and microenvironmental analyses. Results so far indicate that very specific rehabilitation techniques are required to enhance site recovery. Native species such as *Deschampsia caespitosa* and *Poa alpina*, either seeded or transplanted in the fall of the year, are more successful than introduced species. Supplementary treatments of fertilizer, lime to increase soil pH, and organic matter incorporated into the soil are absolutely essential in alpine areas.

THE USE OF RANGE PLANTS IN THE STABILIZATION OF PHYTOTOXIC MINING WASTES.

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The problems of environmental pollution originating from mining wastes can be prevented by stabilizing these wastes either mechanically or biologically. In the long term, biological stabilization using a plant cover, is more attractive because of its permanent nature. In general the majority of work in this biological field has been directed towards the amelioration of the phytotoxic factors in mining wastes, thereby enabling plant growth.

The main factors influencing plant growth on the mining wastes in this study were mean total values of 1980 ppm arsenic, 1180 ppm copper and 2130 ppm nickel; specific conductivities of up to 40200 micromhos and an acute deficiency of one or two of the plant macronutrients nitrogen, phosphorus and potassium.

Following the well established theory that plants exhibit varying tolerances to toxic situations, a careful programme of plant selection produced a number of range plants for testing in field experiments on slimes dams. Although plants reacted differently to different slimes materials, spectacular plant growth was achieved in all situations with a minimum of artificial aid. Estimated costs of establishment were R\$200 per hectare.

This study illustrates that more efficient stabilization programmes are to be found in the careful selection of toxic tolerant populations of range plants.

REGENERATION OF HIGH MOUNTAIN RANGELAND SITES IN NEW ZEALAND AFTER CULTURAL TREATMENT.

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On mountain rangeland in New Zealand, many severely deteriorated sites persist long after the cultural pattern has changed. Combinations of factors such as very low soil fertility and harmful interactions of climate and poor soil structure prevent natural recovery. Despite lack of natural regeneration on these sites, the evidence for the ability of many native species to survive for very long periods on low fertility soils makes their presence desirable and to be encouraged. Research using fertilisers, grasses and legumes has demonstrated the feasibility of producing a stabilising primary cover of non-native herbaceous vegetation on severely depleted sites. Given the presence of this stabilising cover for a period of five to ten years, the range of herbaceous and shrubby native species is encouraged, but the degree of success depends on proximity of a natural seed source. Because of the high costs of treatment, future work must be concentrated on those sites that will give maximum benefit in soil and water values, and in rapidly building experience in the increase of seed supplies and in handling seed and vegetative material for propagation of high altitude species.

POTENTIAL OF CERTAIN RANGE SPECIES FOR IMPROVEMENT OF BURNED BRUSHLANDS IN GREECE.

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Relatively large areas of State owned brushlands are burned by wild fires in Greece every year. Existing management regulations prohibit livestock grazing from these areas for at least ten years following the fire without anticipating their improvement by seeding range species.

The potential of improved varieties of orchardgrass (*Dactylis glomerata*), hardinggrass (*Phalaris tuberosa*) and rose clover (*Trifolium hirtum*) for improvement of burned brushlands for livestock and wildlife and soil protection as well was investigated in the years 1973 to 1976. The experiment was carried out in a maquis type (evergreen) brushland burned by a wildfire in Chalkidiki, Northern Greece. Species were planted after the fire in three combinations: orchardgrass alone, with hardinggrass and with hardinggrass and rose clover; and four seeding rates: 5, 10, 15, and 20 kg/ha. Their establishment, growth and persistence for three consecutive seasons after the fire and seeding was studied.

Orchardgrass was found to be a very promising species for improvement of burned brushlands provided that it is used in selected sites of good soil depth. Hardinggrass and rose clover showed poor establishment and limited persistence. Herbage yield was found significantly higher in the seeded plots than in the controls. The results are compared with findings in other countries and their significance to practice is discussed in relation to the wildfire and grazing problem of Greece.

RECLAIMING A STRIP-MINED CORAL LIMESTONE QUARRY IN KENYA.

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Reclamation need not stop with stabilization of spoils. Rather, such areas can be developed into functioning ecosystems of great variety and value.

A strip-mined coral limestone quarry in Kenya has been successfully reclaimed with timber, fodder, fruit trees and aquaculture. An area of 260,000 m² has been reclaimed in seven years. The largest timber trees are 22 m high, increasing and expanding the forest by seed, and providing posts and construction poles. Due to the massive introduction of millipeds and compost bacteria, humus is building up rapidly, even in areas where *Casuarina* were planted as a rangeland culture. Mushrooms flourish in the rainy season. On high-level grounds, *Prosopis* provide nectar for honey and pods for fodder. Mangoes, guavas and bananas are doing well on the quarry floor without irrigation, due to a special technique that is described in the paper.

Ferns, grasses, legumes and bushes, which were sown as understory vegetation, have helped in balancing the ecosystem, increasing local wildlife, and establishing introduced animals. Over 90 species of birds and mammals have been observed. Introduced antelope browse mainly on trees and bushes. A hippopotamus feeds on the grass and returns nutrition to the ponds where fish flourish.

Approximately 20,000 m² of excavations filled naturally with saline ground water. Algae and Plancton

growth was promoted by applying farm yard manure. Then water plants and edible fresh water fish (Tilapia and others) were introduced to establish a small fishery and pay part of the reclamation cost until

return from harvested trees could be expected. The ponds are used primarily to produce Tilapia fingerlings for stocking fish-fattening tanks.

NOTES

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THE SOCIETY PUBLISHES the bimonthly JOURNAL OF RANGE MANAGEMENT, which contains research reports, articles of general interest, management notes, technical notes, viewpoints, and book reviews. Complementing this publication is RANGEMAN'S JOURNAL, which appears in alternate months and carries national and international news of interest to the profession, Society news, and discussions of current topics germane to rangeland management and use.

HEADQUARTERS OF THE SOCIETY are located at 2760 West Fifth Avenue, Denver, Colorado 80204, U.S.A.