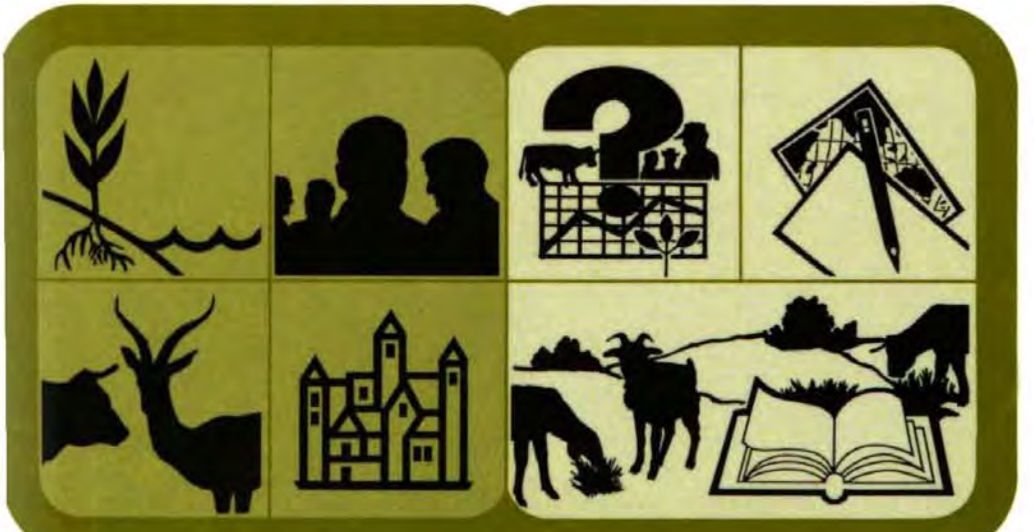
ARID AND SEMIARID LANDS

Sustainable Use and Management in Developing Countries



ARID AND SEMIARID LANDS:
Sustainable Use and Management in Developing Countries

Prepared for:

AID/NPS Natural Resources Expanded Information Base Project
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Preface

This review paper and its associated design aids are part of a project that formally began in 1979, when the National Park Service (NPS) and the United States Agency for International Development (USAID) signed an agreement to begin working together in natural resource management. This agreement resulted from USAID's increasing involvement with natural resources and the realization that personnel within the agency were generally not specialized in environmental protection or natural resource management. "Arid and semiarid lands" was one of three biogeographical provinces targeted by NPS for the improvement of the ability of USAID and other development assistance agencies to incorporate natural resource considerations into their project design. The other provinces are the coastal zones and the humid tropics. The AID/NPS project is preparing review papers, case studies, and project design aids/guidelines for each of these provinces.

Although this review paper tries to be global in perspective, emphasis is given to Africa. The objectives of the review paper are 1) to review what is known concerning the ecological use and management of rangeland resources appropriate for developing countries, and 2) to document the need for integrated approaches in the development of arid and semiarid land resources. Many development efforts in arid and semiarid regions have failed to meet expectations. Much of this can be attributed to narrow sectoral planning approaches that do not adequately address the natural, social, economic, and institutional consideratons in the region. The more successful projects often use an approach in which a "package" of land uses are developed for a region to meet local needs.

A companion volume on project-design guidelines will provide development agencies with specific materials that describe the ecological and socioeconomic considerations for project planning, implementation, and evaluation.

Acknowledgments

This review paper was reviewed by approximately 30 people. Some had overseas experience in rangeland development, others are professionals from developing nations, and others are currently in donor institutions. These reviews provided valuable inputs into the final manuscript. Major contributions throughout its preparation were made by Alan H. Jacobs, James G. Teer, Charles E. Poulton, and James O'Rourke.

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Executive Summary

More than half of the earth's land surface is arid or semiarid lands. They are the major land resource in most developing countries. But in those countries the demand for goods and services from these lands is increasing beyond the ability of the traditional management systems to meet them. Conflicts between various users of the resources are increasing as those resources are diminishing. There is an urgent need for responsible management of the world's arid and semiarid land resources.

The term rangelands had its origin in the United States in the late 1800s and includes those uncultivated lands that can be browsed or grazed by wild or domestic animals. Because most arid and semiarid lands are not cultivated they are considered to be rangelands. In different parts of the world this type of land is known by many names (i.e., savanna, veld, steppe, dryland, arid and semiarid land, native pasture, grazing land, bush, grassland, or pampas).

Rangeland management has two sets of goals. One is the protection, conservation, and improvement of the soil, water, plant, and animal resources. The other is the well-being of the people dependent on rangeland production. This task of protecting resources from long-term degradation while trying to feed a hungry world is not a simple one. But it is a task that can be eased by taking a more holistic approach to the development process.

Behind such an approach is the realization that the parts of the whole are not isolated; that the entire production system -- not just part of it -- should be considered and managed to meet the short- and long-term needs and goals of people. The effect that projects and new technologies have on the greater environment should be considered early in the project-planning process.

This paper and the design-aid package are intended to help development agencies consider the total ecological and socioeconomic environment as they plan, implement, and evaluate projects involving rangelands. The first section of the paper is a review of rangeland classifications and a description of the people, livestock, and wildlife that share the land. It also contains a discussion of what must be known about developing-country infrastructures before any development project is planned. The second portion of the paper looks at processes and interventions that can help to meet the long-term needs of the people who depend on rangelands.

Lessons Learned

There are lessons from development successes and failures in the past that should motivate researchers and implementers to consider economic, political, social, and ecological matters in project design. Among those lessons:

- Provision should be made for long-term monitoring, both during and after project implementation.

- Assessment activities should be carried out in support of other development activities. This need not be expensive or complex to be effective.

- Because of complex and changing social and ecological characteristics of rangeland production systems, projects need to be long term (10 to 20 years).

- The ability of the host country to fund and participate in projects after donor support ends should be a key element in the planning process.

- Establishment of documentation centers could reduce some unnecessary duplication of effort brought about by lack of communication among development projects.

- Holistic approaches should be used during project planning, implementation, evaluation, and monitoring so that interdisciplinary teamwork becomes integral to the process.

- A higher proportion of counterpart training should be done in-country.

- Development projects should provide inducements to trained staff to stay and be productive in the more remote areas in which range projects are carried out.

- To prevent degradation of the natural resource base upon which people of the rangelands depend, the consequences of interventions to the rangeland system must be adequately assessed before interventions are made.

- The planning process must be carried out with -- and not simply for -- people.

- Technologies designed in developed countries are not necessarily appropriate for developing countries.

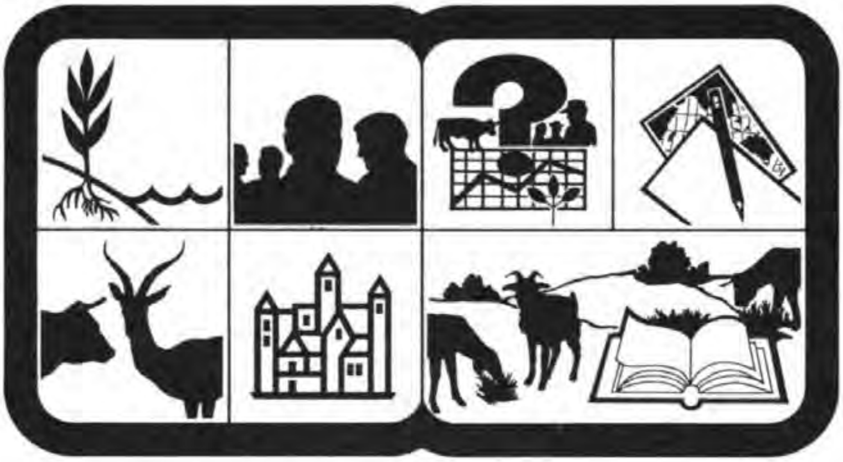
- Planners should note that overcoming technical constraints often proves to be more difficult than anticipated.

- Careful evaluation must be made before people are encouraged to grow crops on marginal lands that are best suited for use of grazing animals, and before agronomic research on these lands is encouraged.

- More attention should be given to multiple-use land-management systems that utilize local knowledge and indigenous plant and animal genetic material available in developing countries.

This paper is a review of what has been learned about the ecological use and management of developing-country rangeland resources and a documentation of the need for an integrated approach to the development of these resources. It is hoped the review paper/design-aid package will be a useful tool to the people designing and carrying out sustainable, sensible development projects.

The Issues



Background and Objectives

Large portions of the land in developing countries are classified as arid or semiarid lands and are located in the tropical and subtropical zones of the world (figure 1). The term rangelands had its origin in the United States in the late 1800s and includes those uncultivated lands that can be browsed or grazed by wild or domestic animals. Because most arid and semi-arid lands are not cultivated they are considered to be rangelands. It should be emphasized that rangelands refers to a "type" of land and not just a "use" of the land. In different parts of the world this type of land is known by many names (i.e., savanna, veld, steppe, dryland, arid and semiarid land, native pasture, grazing land, bush, grassland, or pampas). This book will generaly use the term rangelands to describe these lands. However, the other synonyms may also appear.

These lands have traditionally supported mostly extensive forms of animal agriculture somewhat in harmony with the indigenous wildlife populations and the intensive cropping systems on adjacent higher-potential lands. Human population trends and development processes in many developing countries have contributed to significant changes in the way rangelands are managed. The demand for goods and services has increased beyond the ability of the traditional management systems to meet them in most developing countries. Conflicts between various resource users have increased as their demands have intensified competition and interactions within a fixed or diminishing land base. In many cases, development activities involving rangelands have been less successful than they should have been.

This review of the use and management of rangeland resources in developing countries is part of an overall effort to increase the effectiveness of development programs in meeting the needs of people now and for future generations. This book is divided into two sections. Section I describes four of the general rangeland system components and discusses the characteristics of these components that development programs should consider to ensure the sustainability of the resource base. Section II describes processes and interventions that can contribute to the attainment of the long-term needs of the people dependent on rangeland systems. The guide lines volume that serves as a companion for this book will help project planners to design integrated development projects.

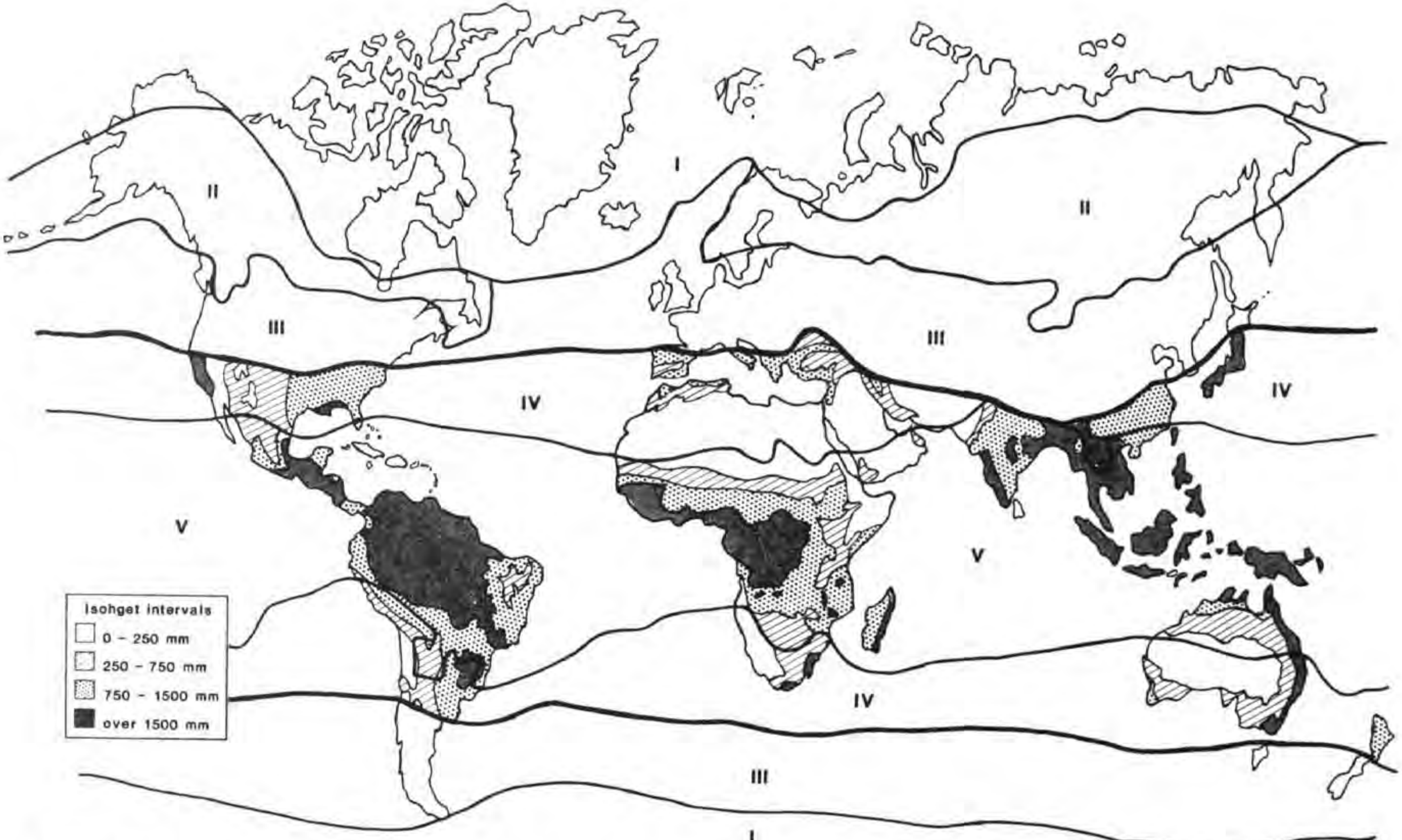


Figure 1. *Mean annual precipitation shown within the tropical and warm-temperature subtropical climatic zones. [Climatic zones: I — polar, II — cold temperate boreal, III — cool-temperate, IV — warm-temperate subtropical, and V — tropical.]*

Rangeland Development Challenges

Stafford Beer in his book "Platform for Change" suggests that new ways of looking at the world will be required if we are to meet the challenges of the future. He expresses this as follows:

> Man is a prisoner of his own way of thinking and of his own stereotypes of himself.
>
> His machine for thinking, the brain, has been programmed to deal with a vanished world.
>
> This old world was characterized by the need to manage *things* stone, wood, iron.
>
> The new world is characterized by the need to manage complexity.
>
> Complexity is the very stuff of today's world.
>
> The tool for handling complexity is ORGANIZATION.
>
> But our concepts of organization belong to the much less complex old world not to the much more complex today's world.
>
> Still less are they adequate to deal with the next epoch of complexification -- in a world of explosive change.

If Beer is right, man must learn to manage whole systems and not just components within the system. M. Casu (1976) expressed this concept when he concluded that the education process in many institutions and in society "involves the training of technicians far more preoccupied in obtaining a given product rather than in managing a space." The term "ecosystem" seems to represent many people's concept of the "space" referred to by Casu.

Prior to 1970, range management often was defined as "the science and art of obtaining maximum livestock production from rangelands consistent with conservation of the land resources." This definition emphasized managing rangelands for a single product -- livestock. The current definition broadens this single-product preoccupation to "the obtaining of an optimal mix of goods and services to meet the needs of mankind." This change is indicative of the growing concern that systems -- not just parts of them -- be managed to meet the needs and goals of the people in whose country such "space" exists.

During the last decade, awareness of the need to manage the "space" and not just to manage for individual products has grown. That awareness has been expressed in laws and policy statements throughout the world. Implementation of the concept has begun. The increased public concern for the "environment" and the volumes of law that have been generated in the developed countries are examples of this trend.

Many development projects have been designed using the thinking of the past in which one "product" is isolated and solutions sought. Many development projects for the poorer countries often look only to short-term needs, such as the alleviation of hunger. While this is perfectly acceptable and legitimate, it must be done in concert with a long-term strategic approach.

Development projects must be designed so that they are both ecologically and socially sound, as well as economically viable. They should result in a measurable improvement over the existing use of such lands for the benefit of people.

Rangeland Production is Energy Efficient

It is argued by many that the world will have too many people within the next 50 years. The reasoning is not necessarily that our land resources will not have the capability of feeding the masses, but rather that the energy resources will be so limited that the production of food and its distribution will be severely curtailed. Continuing depletion of the world's fossil fuels, even within the near future, will necessitate the development of food-production systems that use less energy.

Because there is so much rangeland in the world, because most of this land has no other low-energy alternative use for food production other than grazing, and because it represents a renewable resource that requires only a slight fossil-fuel input for meat and milk production, it seems advisable where human food supplies are limiting that this land be managed at or near its potential. This assumes that long-term conservation goals will also be met.

The terms "cultural" or "subsidized" energy have been used because the energy for food production usually comes from more sources than just the direct fossil-fuel inputs. Cultural energy comprises all inputs except the direct conversion of solar energy by plants and includes labor, manufacture of machinery, transportation, tillage, production of fertilizer and pesticides, processing material, and marketing.

The price of most foods is closely related to the energy expended in their production. Thus, fossil-fuel inputs in the future will favor some food-production systems, making inputs of cultural energy very important in planning and modifying food systems for the future. Rangelands provide food and fiber products with a small expenditure of energy and this alone justifies emphasis on rangeland-development projects.

Regardless of how agriculture changes in the future, whether it becomes increasingly mechanized or other alternatives are used to permit increased output per acre of arable lands without substantial increases in fossil fuels, the major land resource in most developing countries is forage on extensive rangeland acreage. Rangeland forage regrows each year without large inputs of cultural energy. It must, however, be well managed if it is to produce at full potential, on a sustained-yield basis, in harmony with the other needs from these lands. Agroforestry for the production of trees, crops, and animals in developing countries exemplifies such a multiple use.

Lessons Learned from Past Intervention

The economic, social, political, and ecological diversity found in developing countries requires that improved project design, implementation, evaluation, and monitoring procedures be incorporated to meet long-term needs. The perceived high percentage of past failures and short-comings for range/livestock projects in developing countries points to this need. Some of the lessons learned from past experience have been summarized and grouped as they relate to the chapters in section II of this book as follows:

Resource Assessment (Ch. 5)

- Long-term monitoring, during and after project implementation, should be provided. Hopefully, the effects of most projects will continue to be seen long after the initial project is completed. In addition, most rangeland areas experience frequent droughts, and monitoring of management strategies through such periods of stress can provide guidelines for improved management.

  Shelford's "law" of tolerance states that the survival and success of an organism is dependent upon the deficiency or excess of any of several factors that may approach the limits of tolerance for that organism. Introductions of both plant and animal species have been made and tested under optimal conditions only to find that when one of these factors (i.e., periodic drought or disease) appears, these introduced species are decimated. Some failures might have been avoided if sufficient testing had been done prior to implementation or if improved monitoring procedures had provided early documentation of stress points. Adapted plant and animal species are critical components of successful rangeland projects.

- Assessment activities should not be carried out in isolation from other development activities. The scale at which assessments are carried out is critically linked to the steps in the planning process. Generally the scale is much broader and less detailed during the early planning stages and becomes much more detailed as it focuses on selected areas for development and the implementation phase begins.

  The scale of assessment will have a dramatic impact on the costs incurred during the planning process. Since there are often other development activities in the same region, it is wise to coordinate assessment activities to reduce costs and ensure that the scale is appropriate to meet the needs.

Planning for Integrated Resource Use (Ch. 6)

- Due to complex and changing social and ecological characteristics of rangeland production systems in developing countries and our general lack of understanding of them, projects need to be long term (10 to 20 years). Changes within these systems occur slowly, and projects that end after 3 to 5 years tend to confound the development process. For example, in 1969 under an FAO (Food and Agriculture Organization, United Nations) program, major inputs were made into the Kiboko and Bachuma research stations to initiate research that would generate information and technology appropriate for Kenya. The FAO support was terminated in 1973 and, although research priorities had been established and some structures and equipment left in place, there was a critical deficiency of trained, motivated staff and of financial resources required to continue the established program of research.

  In 1979, the realization of the need for a solid research base for rangelands in East Africa prompted the Government of Kenya and USAID to begin another 6-year range-research development project. This type of up-and-down cycle of development is not unique and must be avoided if long-term goals are to be met.

- Projects are often established that require a significant level of funding to support the recurrent costs after donor support ends. The ability of the host country to continue support or find support for the recurrent costs of any implementation activities beyond the anticipated technical-assistance phase must be considered.

- Most of the political boundaries do not correspond to ecological or social boundaries found on the rangelands in developing regions. There are also many different donors who often speak and (or) publish in different languages. Often, development projects "reinvent the wheel" because of the lack of communi- cation. Although the validation of management strategies in different environments is important, the establishment and use of "documentation centers" could reduce some of the unnecessary duplication of effort.

- A more holistic approach should be taken during project planning, implementation, evaluation, and monitoring. Only in recent years have social scientists contributed to the so-called biological research areas and vice versa. In the past the two types of scientists were often brought together after the fact instead of being involved in the planning and early implementation phases. This has been, in part, due to the separate academic training programs that most social and biological scientists have had in the past. Both have had very little common background that promoted communication between them. The main difficulty is that problems are defined as functions of disciplines, often ignoring interacting elements. Fortunately, this problem seems to be diminishing but continued interdisciplinary teamwork and conceptional expansion must occur to ensure that teams work together in all phases of rangeland development projects. The holistic approach is not easy and sometimes requires more time during the planning phases, but the long-term success of development in these highly diverse systems requires the broader perspective that is obtained only by all disciplines working together.

- A higher proportion of the counterpart training should be done in-country. In countries where the education system has not been developed to the level where the desired training is possible, training programs should be selected that will offer the counterpart a background and skills that can be directly related to the ecological and social environment the graduate will be working in after training. Training and education must bring disciplines together into a common focus. This can be accomplished by providing projects with the flexibility to have the research portions of advanced-degree training programs conducted within their home country. Major advisors in the universities should be encouraged to visit the research site and assist in the development of the research. Project staff could serve on the graduate committees of the counterparts and provide the supervision and guidance for the field work and other in-country degree work. Field training and integration of field and academic learning is important in educational programs.

- Scientists trained within a development project often move to another job or even another country after their formal training is completed. Rangeland work is by nature more isolated from the benefits of urban living and it is often difficult to provide the amenities of life like schooling facilities for dependants, health care, shopping areas, and social/recreational facilities desired by the trained scientists. Salaries and other professional benefits are also insufficient to retain trained staff in many rangeland work areas. Development projects need to, where possible, provide some method to induce trained staff to stay and be productive in these more remote areas.

- There are numerous examples where development and charitable institutions have attempted to assist rangeland peoples without adequately assessing or understanding the total system and the consequences of interventions. Wells have been developed; animal-management and land-management strategies enforced; schools, churches, and health clinics built; and market infrastructures established. The result of many of these well-intended efforts has been the degradation of the natural resource base upon which these people have depended.

- The planning process must be carried out with and not simply for people. The involvement of host country representatives will help to ensure socially sound development activities. Questions like who are the direct beneficiaries to be; what is the likelihood that the program will contribute to a solution to their perceived needs; and why is this activity more important than some other activity are all likely to be better answered if representatives from the host country are involved throughout the planning process.

Rangeland Management and Improvement (Ch.7)

- Technologies developed in the United States, Europe, Australia, and other developed areas are not necessarily appropriate or feasible for developing countries. Most developing nations have tropical climates, particular socioeconomic infrastructures, varying but low levels of total wealth, and poor quality of renewable natural resources. Even though the ecological principles behind worldwide technologies remain constant, their actual application involves practical alterations in the tropical rangeland systems.

- Overcoming technical constraints, such as control of the tsetse fly, has proven to be more difficult than anticipated. This is at least partly due to the tendency to implement technical procedures as practiced in the donor country, but without suitable modification.

- People often attempt to grow plants for food (crops) on marginal lands that are best suited for grazing animals. The uncertainty of soil moisture and the unpredictability of rain typify rangelands. Every developed nation with arid and semiarid lands has experienced problems from attempting to cultivate them. Encouraging people to farm these lands and encouraging agronomic research on these lands are issues that must be carefully evaluated before embarking on any development project.

- More attention should be given to multiple-use land-management systems that utilize local knowledge and indigenous plant and animal genetic material. Exotic species have been introduced, tested for a short time, and suggested for adoption only to have these species dramatically affected by periodic drought, parasitic infestation, adverse social acceptability, or disease. Local varieties have adapted through time to the variety of highly fluctuating conditions that typify each rangeland area. There are few miracle plant or animal varieties that have universal potential to be more productive on a sustained basis than properly managed local varieties.

Annotated Bibliography

Beer, Stafford. 1975. Platform for Change. John Wiley and Sons Ltd., Bristol, England. 457 pp.

This book examines the way we currently view our world and its affect on management. Beer theorizes that the world is changing and that we are managing it using tools and concepts from our views of a now-vanished world. Arguments are presented to support this hypothesis, with suggestions of ways to meet the needs of the present and future world.

Moris, Jon R. 1981. Managing Induced Rural Development. International Development Institute, Bloomington, IN. 190 pp.

This book has 10 chapters that discuss the development process in rangeland areas. Chapter 8 presents an excellent case study of the Maasai Range Development Project. This project was sponsored by USAID in three phases running from 1970 to 1980. The case study offers several lessons learned from rural development programs generally.

Wont van den, Bor (Ed.). 1983. The Art of Beginning. Pudoc Wageningen, P.O. Box 4, 6700 AA, Wageningen, Netherlands. 174 pp.

This book contains 12 case studies giving the first experiences and problems of western expatriates in developing countries with special emphasis on rural development and rural education. It also contains an annotated bibliography of other case studies.

Section I

Rangeland System Components

Section I has four chapters that deal with major rangeland systems concentrating on vegetation, the peoples that depend on these systems and their problems in living there, the domestic and wild animals that share the rangelands as well as provide for the human inhabitants of the rangelands, and the governmental policies and institutions that so frequently control the development of rangelands for their desired production.

Chapter 1

Major Rangeland Systems

Deserts, shrublands, grasslands, and forests support millions of domestic and wild herbivores upon which the human race depends for meat, milk, hides, fiber, power, transportation, aesthetic value, and other products. For many groups of people the grazing of animals provides their very sustenance. These grazing lands, here called rangelands, amount to nearly 50% of the earth's land surface. Many classifications of rangeland systems have been proposed; this chapter takes a broad approach to rangelands and separates them into seven categories for description according to the dominant vegetation, climate, major native and domestic animals, soil, water relations, current use, and management problems. Most of the broad categories of vegetational systems are seen locally almost everywhere as a mosaic of different vegetational types. The more detailed landscape information that is required for planning of individual projects will be found as suggestions in later chapters.

Objectives and Coverage

Rangeland systems include deserts, shrublands, grasslands, and open forests that support domestic and wild herbivores. These lands amount to nearly 50% of the earth's land surface and exclude only dense and commercial forests, cultivated land, large inland bodies of water, urban-industrial areas, and ice-covered regions. Some rangeland vegetation is derived from forests after timber harvesting and from land on which cultivation has been abandoned. Grazing land uses may be included in combination with timber and crops in what has recently come to be known as agroforestry.

The principal products from rangeland are meat, milk, fiber, and hides. Other rangeland values go far beyond grazing by animals to include values for water, recreation, fuel, and antiquities, to name a few. Rangeland management has two sets of goals. One is the protection, conservation, improvement, and continued welfare of the resources of land, water, plants, and animals. The other is the increased well-being of the rangeland peoples and others dependent on rangeland production. These aims may be global or local in scale, different in emphasis, and short- or long-term. They are inextricably mixed in complex systems that include human welfare, market economy, government, and conservation. This chapter describes the large ecosystems in terms of biotic resources, constraints, values, and managerial problems. It is a macro approach based on the proposition that many rangeland management problems and technologies are regional or even global in nature. This is the base from which microanalysis, say a country-aid project, can draw basic principles and widely accepted information.

Many vegetational classification schemes have been proposed but none universally accepted. The one in this chapter is for purposes of rangeland planning and management and makes no claim to being perfectly ecological, physiological, or physiographic in approach. The names are merely convenient labels for the present purposes. The almost total lack of maps and analysis of the world's rangeland resources requires considerable interpretation of botanical and geological information as well as of plant-community descriptions.

An aspect of the problem is illustrated by a vegetational transect across Africa from the Sahara Desert to the rain forest of the Congo River basin. Figure 2 illustrates the soil development and vegetional forms. The belts may be labeled as desert, savanna, and humid forest. In another scheme, the terms Saharan, Sahelian, Sudanian, and Guinean zones are used, but this applies only to Africa. Other schemes divide these zones into small units. The arbitrary classification used here is like Bourliere's (1983), except that his savanna is described in two parts according to the height and nature of the grasses.

Seven major rangeland systems are described. It is a small and comprehensible list in contrast to the many categories in most geographic treatises on vegetation and soil. The deficiency of broad coverage for local planning is minimized because these landscape types are often locally mixed and many principal forage and browse plants occur over wider areas than do the trees. The abundance and growth forms of trees are commonly the criteria for broad vegetational types.

The systems are arranged in decreasing order of total value to countries and occupying peoples. The aim is to describe what each system is, where it is located, what uses are made of it, and the major range management problems and opportunities associated with it.

Savannas with Tall Grasses

Scattered trees, such as *Acacia tortilis* and other woody plants on the Serengeti Plains in Tanzania or the palm *Borassus aethiopum* community in the Ivory Coast, with a continuous understory of grasses 25 cm to 1.5 m or 2 m in height, occupy thousands of hectares of land in the tropics where wet and dry seasons alternate. The largest examples of these orchard-like grass-tree mixtures, known as savannas, cross Africa in irregular bands 8°N to 15°N and again 15°S to 20°S.

The general view of this zone is grassland with scattered trees and shrubs that may be in regular distribution as an orchard or scattered irregularly as individuals or clumps. The clumps often center on and around termite mounds. Some wide expanses of grassland occur without upland trees, as the *Andropogon* prairies of central North America and parts of the Serengeti Plains in Tanzania. Riverine trees are never far distant. Herbaceous communities with thick tree canopies are called wooded savannas, and every gradation of tree-grass proportions exists in the transition from rain forest to desert.

The 1983 book edited by F. Bourliere on tropical savannas summarizes the available ecological information on vegetation and animal communities. In this book, savannas with tall grasses include the tree and shrub savannas and the woodlands of that publication.

The abiotic characteristics of the type are precipitation of 350 mm to 700 mm (on sites overlapping the wetter savanna types rainfall may reach as much as 1000 mm), wide ranges in the daily and yearly temperatures, frequent low humidity, and intense sunlight. Rainfall comes from storms of irregular intensity and incidence. The growing period is seasonal (during the wet months) in contrast to that of humid forests, which is yearlong, and of deserts, which is irregular. Droughts are common. Rainfed raising of crops is risky below 800 mm to 900 mm of rainfall and farmers must resort to sites where water naturally accumulates, is stored in deep soil, or is supplemented through irrigation. Planting is often done only in years of high rainfall. Deficiencies in soil fertility commonly become limiting to crops when rainfall exceeds 600 mm.

Most of the region is best suited for grazing by ungulates, both domestic and wild. This is in part because net primary production is at relatively high levels and much greater than that of forests when compared as a ratio with standing crop. Organic matter is turned over rapidly, not only by the

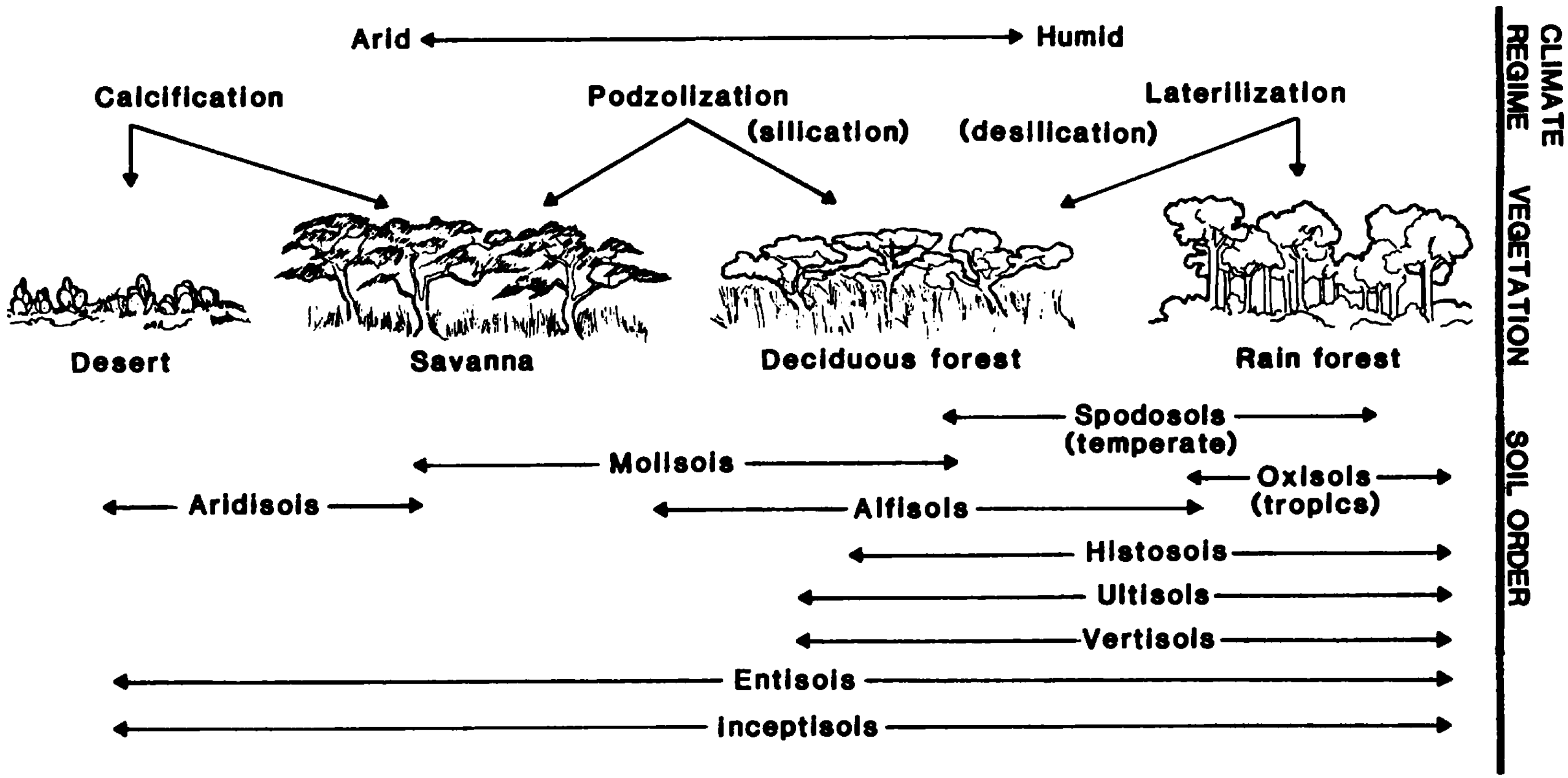


Figure 2. General relationships among climate, vegetation, and soils [redrawn from Erhlich et al. (1977)].

large grazing animals but also by invertebrates. Termites have been estimated to consume as much as one-third of the standing herbaceous crop each year. Most of the grassland net primary production is immediately available as food for grazers, although much is of low quality for domestic animals. Decomposition is less rapid in grasslands than in tropical forests, but is still important in the cycling of nutrients. It is well to note that roughly 20% of the nitrogen in tropical forests is in plant materials, but only 5% to 10% in savannas. Soils are as varied in these grasslands as anywhere in the world and few generalities can be found. However, the upland soils are usually well-drained, without a continuous litter cover, have an organic carbon content of less than 2%, and a low clay content of the kaolinitic type. As termite mounds disintegrate, fine materials previously carried from below are added to the soil surface.

The tallgrass-savanna zone across northern Africa south of the Sahara is characterized by herbaceous understory vegetation of *Pennisetum* spp. and *Andropogon* spp. on the south and west side, *Themeda triandra* farther north, and species of the genera *Aristida, Eragrostis,* and *Cenchrus* adjoining the desert. Most of these grasses grow taller than 80 cm. Similarly, the wet-side trees are typified by *Acacia, Bauhinia,* and *Balanites;* by other *Acacias* and *Combretum* spp. at a lower rainfall; and by shrubby *Acacias* at the lowest rainfall. Several short *Hyparrhenia* species are found under tree canopy and in the open grassland throughout. Vegetation with the same general appearance occurs in East Africa, but it is more varied due to large differences in topographic and local soil-moisture conditions. In central and southern Africa the transitional vegetation between woodland and grassland is locally named mopane woodland, and is dominated by *Acacia* spp. and *Colophospermum mopane* and by grasses in the genera *Themeda, Hyparrhenia, Andropogon,* and *Panicum.* Central Madagascar has tallgrass savanna dominated by the trees *Commiphora* spp. and *Dalbergia* spp. and two grasses, *Hyparrhenia rufà* and *Heteropogon contortus. Leucaena leucocephala,* a valuable forage legume, has become important in the higher rainfall belts of Madagascar.

Peninsular India and eastern Pakistan have extensive areas with vegetation of the same savanna appearance, trees and shrubs in the genera *Acacia, Mimosa,* and *Ziziphus,* and some of the same species that occur in Africa. An obvious addition is the widespread distribution of the introduced fodder tree *Prosopis cineraria.* The monsoon climate in this area gives a wet period from June to November and from 200 mm of precipitation in the west to 2000 mm in southeast Asia. Islands of tallgrass savanna occur in southeast Asia but they are of little consequence. Derived from forest through sifting cultivation, frequent burning, and overgrazing, they soon return to forest. The semiarid northwestern part of India is characterized by grassland of *Dichanthium, Cenchrus,* and *Lasiurus,* and by woody *Acacias* and *Prosopis.*

South America has extensive areas of tallgrass savanna on the Venezuelan, Guyanese, and Colombian llanos, the northern Argentine pampas, and the campos cerrados (mixed grass and shrub vegetation) of central to eastern Brazil. Several genera of grasses with many species, such as *Axonopus, Elyonurus, Paspalum, Ichnanthus, Trachypogon, Panicum,* and *Andropogon* characterize grasslands from 0.5 m to 1.25 m in height. A few savanna trees to heights of 15 m in the genera *Byrsonima* and *Bowdichia* are present, but South America has large areas of relatively pure grassland. The tropical ungulate fauna of 21 species in South America is much less diverse than in Africa, where there are 91 species. Of the 21, 3 tapirs, 3 peccaries, and some of the deer are essentially forest dwellers.

Livestock feed on leaves and fruit of the tree species in the genera *Mimosa, Acacia, Prosopis,* and *Cassia* in South American savannas. The type in Australia and Papua New Guinea has a thin tree canopy of *Eucalyptus, Melaleuca, Bauhinia,* and thornless *Acacia* with an understory of *Themeda, Bothriochloa, Plectrachne, Estrebla,* and *Triodia.* The dominance of *Aristida* usually means that overgrazing occurred at one time, or it may be the principal dominant on drier sites.

Savannas with continuous understory grasslands through east and central Africa, North and South America, and Australia have been the center of evolution for many large herbivorous species and are the most productive ecosystems for wildlife in the world. All continents had such assemblages of herbivores in prehistory and in later times. For example, the New World had many kinds of horses and camelids as well as elephants. The productivity and diversity afforded by savannas and grasslands supported these extremely rich herds of herbivores and attendant

Figure 3. *A savanna in Africa with a continuous cover of medium-height grasses and an open canopy of* Acacia. *Both the livestock and the vegetation are in excellent condition.*

organisms. Such diversity in kinds, numbers, and biomass was made possible by niche separation in the animals' food habits, activity patterns, and migrations, as well as by adaptations in digestive processes and for low water requirements.

These same areas were the centers of evolution of many forage grasses and woody browse plants that supported the large herbivores. The vegetation has been subjected to frequent and continuous defoliation because animals must graze on rangeland almost every day. Defoliation through grazing becomes severe when natural droughts reduce primary production of forage and when animal populations cycle into large numbers. In addition to grazing, frequent fires reduce herbage in the tropical dry seasons. Foraging animals graze selectively, thereby exerting different degrees of impact on the different plant species. Animals trample the plants, break down limbs or even whole trees, and influence the cycling and distribution of minerals. The point is that grazing in the savannas and pure grasslands is a natural and long-term influence. It is well known that overgrazing temporarily destroys grasslands and savannas. No grazing at all also fosters vegetational changes, usually toward nongrass dominants. Fortunately, reasonable grazing by species useful for human food is beneficial to grassland systems. These ecosystems evolved under grazing and burning and are best maintained under these same conditions.

Under the variable impacts of grazing, fire, and climate, trees in the savanna tend to be thinly spaced per unit area. They regenerate only on a periodic basis when cycles of climate, fire, and animals permit. When these three factors influencing primary production operate in balance, including many yearly and cyclic disturbances, the whole system maintains a varying stability. This has often been labeled as a dynamic climax. It appears that the savanna with tall grasses as described here is more clearly climax than the savanna-woodland vegetation at higher rainfalls.

When savannas are destroyed, they tend to replace themselves. Elephants reduce trees but the trees increase when browsing pressures are low during above-normal rainfall periods as has happened in the Tsavo Park in Kenya. *Themeda* and *Hyparrhenia* grassland in East Africa in times of drought and close grazing gives way to shorter perennial grasses such as *Digitaria* spp. Further deterioration is indicated by an abundance of annual grasses (*Aristida, Eragrostis)* and often unpalatable annual forbs like *Sida* spp. Gradually increasing numbers of domestic herds have accelerated deterioration of range conditions but the destruction is seldom complete. Above-average rainfall always brings germination and plant establishment, vigorous growth, and an overall regeneration that often eliminates obvious signs of previous unfavorable conditions. Even severely grazed areas near water will improve under management. While vegetation in this region may be subjected to more severe fluctuations in producing food than the wetter rangelands of the world, it also has a great resiliency and quickly returns to predrought conditions, if given a chance.

Animal nutritional problems in this vegetational region are typical of other tallgrass regions. Grasses are of highest nutritional quality during their earliest growth and lose quality rapidly as they near maturity. Most shrubs and trees maintain green leaves during the dry season and store food in twigs and fruits. Browsing supplements the quality of animal diets during dry periods, especially when the browse is from leguminous plants. The culture and use of tree fodders save many animals and people during drought times. Although the quantity of grass production decreases in dry years, the quality often increases because the smaller plants have less fiber. Supplementary pastures with seeded legumes certainly improve forage quality.

Hydrologic research in the savannas is scarce, but general observations have been made in many places. Where slopes are less than 3%, runoff is usually low. Runoff and erosion will accelerate on slopes steeper than this when the vegetation is abused by grazing or following disturbances such as fire. Differences in plant cover, soil depth, and mean annual precipitation are great enough to foster high potential runoff and erosion. Sediment yields have been measured from 0 t/ha/yr to 20 t/ha/yr. Grazing systems may have beneficial or detrimental affects on the water balance and soil stability. Short duration; high-intensity, low-frequency; and other grazing systems have on occasion reduced cover conditions to unnatural levels. Even though these low cover levels may be temporary, heavy rainfall during this time may be disastrous. It is difficult to increase runoff without increasing erosion on these rangelands.

Large wild animals characteristic of the savanna and tallgrass areas of Africa include the zebra, wildebeest, hartebeest, topi, impala, and Grant's and other gazelles; in the brushy areas such animals as the eland, kudu, and gerenuk are found. Closely related races of these species are found in different parts of Africa. Many more herbivores could be listed and large numbers of some abound in national parks and reserves. Africa still has many species of large herbivores in considerable numbers outside the reserves. Wildlife aspects of major rangeland systems are given in chapter 3.

Deciduous Forests with High Grasses

This type has had a wide variety of names including tropical dry forest, forest and savanna mosaic, savanna woodland, and wooded savanna. As a group of names they convey the concept of a thin, deciduous tree canopy that is more or less continuous or closed, and a continuous grass understory that ranges from relatively thin to very dense. A few tree species are evergreen and many deciduous trees come into leaf before the rains. The grasses in this type are taller than 1.5 m and some may reach 4 m to 5 m. The vegetation is more nearly forest and has a taller understory than the savannas with tall grasses.

The wet season varies from 5 to 8 months in length; annual precipitation is as high as 1500 mm but seldom as low as 700 mm. Thorn shrubs occur in the understory but frequent burning reduces them and increases accessibility to wild and domestic grazing animals. In Africa the deciduous forests adjoin the humid equatorial forests between 6°N and 10°N and 5°S and 15°S, but they are common in moist situations as far as 30°

north and 30° south of the equator, including islands in steppe regions. The boundary between this vegetation and the savannas described earlier is indistinct, but the major characteristics of this area are derivation from forests, more browsing animals in the fauna, more shifting cultivation, and a plant succession that obviously tends more toward forest than open savanna. Deficiency in soil fertility is more limiting than in the savanna type. From a land-management perspective, it has major problems with invasions of woody plants into fields and rangelands.

Closed canopy forests of up to 25 m in height with rainfalls of more than 1000 mm include an evergreen type in Zaire dominated by *Diospyros hoyleana* and the vine *Combretum microphyllum*. Deciduous closed types have *Albizia* in West Africa, *Isoberlinia* in central Africa, and the distinctive and widely distributed baobab (*Adansonia digitata*) along with *Combretum, Acacia,* and *Commiphora.* The type is sensitive to fire and may be considered as intermediate between *Brachystegia* woodland and savanna. Another closed type is the partly evergreen and deciduous thicket, which is so dense that it is largely impenetrable by humans. In Angola, one often finds *Dichrostachys* and *Strychnos* on alluvial soils. Another excellent example is the well-known Itigi thicket in Tanzania. Succulent thickets composed of *Euphorbia* and *Sansevieria* are common in the Karamoja region of northern Uganda.

In Zimbabwe and Angola the moderately open woodland is known as miombo. It is dominated by *Brachystegia, Afzelia,* and *Julbernardia* and by high grasses in the genera *Hyparrhenia, Pennisetum, Panicum, Loudetia,* and others. Frequent burning favors *Themeda* and other medium

Figure 4. *Many of the high grasses are taller than an adult person, as shown in this wooded savanna in Malawi.*

height grasses. *Cenchrus ciliaris* is common in similar areas in Madagascar. *Butyrospermum* occurs near the rain-forest border in West Africa, and leguminous woody plants are common throughout. *Terminalia* in abundance often indicates poorly drained clay soil and abandoned farmland.

In northeastern India with rainfall over 1000 mm, the vegetation is derived from forests. *Acacia, Butea,* and *Ziziphus* remain common with a grass understory of *Phragmites, Saccharum,* and *Imperata* on wet sites and a combination of *Dichanthium* and *Bothriochloa* on well-drained sites. Open *Dipterocarpus* forests in southeast Asia that appear as forested savannas were all derived from forest, quickly return to forest, and will be discussed in the section on rain forests.

Thin forests with lightly touching tree canopies as much as 25 m above the ground occur in the dry-forest savanna of tropical America. However, the tree genera and species are different, including *Bauhinia, Byrsonima,* and *Quercus* in Mexico. The grass understory is similar to that in the open savanna. In northern Australia, the woodland savanna is dominated by numerous species of *Eucalyptus, Acacia, Bauhinia, Grevillea, Melaleuca,* and others. On clay soils near the Australian north coast, the tall annual grass *Sorghum plumosum* dominates the understory and grassland vegetation. Other common grasses are *Heteropogon, Panicum, Chrysopogon,* and *Themeda.*

Soils generally are deep and have a high erosion potential. When these lands are in fair or better condition, runoff and erosion rates are low, but on degraded lands up to 15% of the precipitation may become runoff. This range ecosystem receives sufficient precipitation to have high amounts of protective cover nearly all the time. When desirable plants are grazed out, weeds quickly replace them, providing cover and organic matter needed for continued high water-infiltration rates.

The accelerating pressures of human occupancy have changed the tropical deciduous forests. Grazing, wood harvesting, annual burning, and shifting cultivation have operated together to cause the reduction of trees and other woody growth. Flooding and droughts are climatically controlled but their effects are aggravated by human activities. The result has been an increasing savanna appearance with scattered trees in a grassland that is little different from savannas, with less than 700 mm of rainfall. Perhaps the changes are most widespread in southeastern Asia and adjacent India, but they also occurred in Africa and South America. This ecosystem type is the home of the gaur cattle *(Bos gaurus)* in India and the banteng *(Bos banteng)* in southeastern Asia, but these animals probably exert little pressure on the vegetation.

The dry season in the deciduous forest with tall, large grasses is a time of stress. As the tall grasses become mature, their nutritive content falls below the maintenance requirements of all domestic animals and many wild herbivores. Mature dry grass may have less than 1% crude protein and over 70% fiber. Browsing on the green and more nutritious leaves and fruits of woody plants supplements the dry-grass forage. The problem of nutritional deficiency is common to all types of livestock management systems (nomadic, transhumant, sedentary) in savannas, dry deciduous forests, and grasslands because the taller grasses are of poor quality. The culture and use of fodder trees and shrubs for forage, especially the legumes, holds a relatively new and attractive promise for improving livestock production in dry, deciduous forests. Saving green feed on the moist sites for dry-season use helps to maintain the nutritive quality of the feed.

The wet season brings new leaves and stems in the herbaceous layer that furnish sufficient proteins, carbohydrates, and vitamins to grazing animals for growth and milk production. Mature domestic and wild animals regain the weight lost during the dry season and the young animals grow rapidly. Under natural conditions, this is when the young are born.

The many different wild ungulates evolved to prefer and digest different kinds of forages. Cattle and wildebeests mostly prefer grass. Others such as the giraffe and rhinoceros select leaves from woody plants. Elephants take sizable quantities of coarse materials while goats, sheep, and Thomson's gazelles nibble the fine grasses, forbs, and shrub leaves. Most require green material, but others like the zebra do well on mature and dry forages. Each animal and certainly each species moves from one habitat to another and eats different plants at different times during the year. All the ruminants have a wide spectrum of kinds of plants on which they can live, but nearly all require feed that has over 5% crude protein; 50% to 60% carbohydrates; vitamins and minerals; and an overall digestibility that cannot fall much below 50%.

In places where grasslands have been invaded by brush or where woody vegetation has been changed to grassland, different guilds of animals and different carrying capacities develop. The multiplicity of diets and niches selected by different herbivores can be used to advantage in managing the savannas. For example, the browsing species tend to keep the shrubs in check, thereby favoring grasses. On the other hand, the grazing species tend to leave the browse alone, favoring the woody plants. In most situations, several species together make the best use of the whole plant biomass. Care must be taken to avoid overgrazing, not just the whole vegetation but also the various components in it. Heavy use of certain plant species by particular animals may be intentionally employed to change the vegetation. These exact relationships are undetermined for tropical grazing lands but nowhere is selection of the right mixture of animal species more important than in the savannas and grasslands, where several species can be used as objects of sport hunting, as meat, and for animal by-products. Another important function is to reduce competition by grass with the planted tree species. The derived savannas, having climates and soils that support trees, are attractive areas for multiple-animal management in combination with food crops and trees.

Several kinds of tsetse flies (*Glossina*) occur in species-specific habitats including streamside thickets, dry forests, woodlands, and *Acacia-Commiphora* bush scattered throughout the African savannas. Warm-blooded wild animals are the reservoirs of the blood parasites (*Trypanosoma*) and the main hosts of the flies that transmit the trypanosomes to humans and livestock, thereby causing sleeping sickness. Since 1900 many unsuccessful attempts have been made to control the disease in livestock, including habitat manipulation, insecticides, and game slaughter. Hope is now placed on developing resistant strains of livestock. Sheep and goats are the least susceptible of the domestic animals. The tsetse problem is one reason for the interest in substituting game farming for livestock.

Vegetational changes follow predictable patterns in savanna areas. Three examples will illustrate different patterns in a general way although many details are still unknown. Let us start with low populations of grazing animals on a grassland where a woodland is expected to develop. The first stage would be increased grass productivity, quickly followed by more animals that would closely graze the grasses. There would be little dry grass, and the reduced fuel would result in infrequent fires, permitting shrubs and trees to increase. With the increase of shrubs and trees, grazers would be replaced by browsing animals, but not eliminated. The grazers would in turn overuse and thin the woody cover, moving the vegetation type back to grass, fire, and grazing animals. Parts of this cycle are well known in Africa, but the interferences by human populations may not allow the cycle to be completed. However, the tendencies are there for both animal types and vegetational compositions to fluctuate in a predictable manner.

The second illustration is successional by definition. Starting with bare soil in East Africa, the first vegetation type is likely to be a stand of annual broad-leaved plants for a year or so. Soon annual grasses, many in the genera *Aristida* and *Eragrostis*, will become dominant. These give way to *Themeda triandra* and other perennial grasses. The shrubs and trees, if they are in the climax, may develop with the herbaceous succession or may become dominant if unbrowsed and if fire is reduced.

The third illustration is the return of miombo after shifting cultivation in central Africa. The first canopy species is *Terminalia sericea* because its root crowns resist farming. The shrub *Hymenocardia acida* is abundant about 7 years after cultivation and the climax *Brachystegia* and *Julbernardia* reach dominance at about 20 years.

Desert Shrub and Grasslands

As was the situation with naming other regional rangeland ecosystems, terminology is inconsistent. These regions receive less than 350 mm of precipitation. The driest is western coastal South America. Those receiving average annual rainfalls of between 50 mm and 200 mm are the large deserts of Africa that lie more than 12° north of the equator and extend to western India, another more than 20° south of the equator in southwestern Africa, a bit of southwest Madagascar, a small area in northeastern Brazil, and central Australia. With a few exceptions, the rainfall in the North American deserts exceeds 100 mm/yr.

Figure 5. Opuntia *is planted for emergency livestock feed in and near the deserts of Africa, southwest Asia, and the Americas.*

The region that receives between 200 mm and 350 mm of rainfall is between desert and savanna. The term "steppe" is frequently applied to the vegetation, although this term may apply to any vegetation type from scattered desert shrubs to a nearly pure grassland where the grasses are less than 80 cm tall. Most commonly, it is an open mixture of grasses and a few shrubs with bare ground between the plants. Most of the grasses have narrow, rolled or folded basal leaves, and many are annuals. Trees of up to 20 m tall are restricted to the watercourses.

Wide temperature fluctuations, as much as 50°C on a diurnal basis, characterize the subtropical and warm deserts. The high temperatures cause high evaporation and reduce the effectiveness of the local and erratic rainfall from convection storms. During most years the desert rainfall is less than the average due to the occasional year with heavy rainfall that raises the average. Due to low annual rainfall and because most storm events provide less than 25 mm of moisture, there is little leaching of minerals, especially the salts, so desert soils are often high in minerals. Some have a high clay content. Most rainfall comes in high-intensity storms; that which falls on clay or poorly aggregated soils runs onto the sandy riverbeds where it rapidly percolates and is stored in the groundwater. Water from these sand rivers is therefore available from relatively shallow wells. Of equal importance, more vegetation is produced on these sites with natural irrigation than would be available with normal rainfall alone. These riverbed sands are the moist sites of deserts and the places where shrubs and grasses with deep roots grow.

Vegetation in the southern Sahara is a mixture of tree and shrubby *Acacias*, with trees along the dry riverbeds and a grassland containing several *Aristida* spp. and other grasses. The Sahel band across Africa is in this zone. Northward, toward drier conditions, the plants become more widely spaced and the shrubs change to include species of *Artemisia*, *Calligonum*, *Haloxylon*, and others. These dominate on different soil-texture types and degrees of mineral concentration. The shrub-like grass *Panicum turgidum* is common in the Arabian and Saharan deserts where the soil is a stabilized sand plain and the rainfall between 50 mm and 100 mm. Shrub deserts of the Karroo and Kalahari in southern Africa have thorny *Acacia* and *Aristida* species in abundance as well as the succulent *Euphorbias* and *Aloes*.

Over most of western and central Australia, deserts support abundant small trees of spineless *Acacias*, *Eucalyptus*, shrubs of *Atriplex* and *Kochia*, and a grass understory of *Aristida*, *Triodia*, and *Eragrostis*. Western coastal South America between approximately 5°S and 25°S, eastern Brazil, and southwestern North America have desert climates, spiny leguminous shrubs in the genera *Acacia*, *Mimosa*, and *Prosopis*, and thorny cactuses. *Prosopis tamarugo*, a promising leguminous fodder tree for other deserts, comes from the coastal sands of Chile where rain may not fall for several years, but where seasonal fog brings moisture to the foliage.

Livestock production is from the herds from large ranches as in Australia, South America, and Mexico, or from nomadic pastoralist herds as in northern Africa and the Near East. Most of every year and over most of the deserts only limited feed is available. The desert in eastern Arabia illustrates the extremes. It has an average annual rainfall of near 75 mm, but the variation is from essentially none to nearly 300 mm. A wet year of the latter amount, perhaps once in 20 years, produces more forage than normal. Nomads move long distances to the abundant grass and stay until it is gone. In years with below-average rainfall, the nomadic custom is frequent moving to take advantage of rainfall patterns and sand-filled valleys where new forages rapidly appear. Arid climates require flexibility in grazing schedules and in movements of livestock for maintenance of animals and forage resources.

Dry-area forages are of higher nutritional quality even when mature than are the tall grasses. The small grasses develop less fiber and tend to have less lignin than the tall grasses of wet climates. Shrub leaves remain alive well into dry seasons and a few grasses have lower stems that remain green for several dry months. *Panicum turgidum* has aerial perennial stems. Forage is seldom leached by rain. Because of scanty fuel, fire is infrequent in most desert areas and may never occur in the driest of them. Seeding of herbaceous forages is difficult, but careful selection of sites that have the potential for water harvesting appears to have possibilities. The possibilities for establishment and use of woody plants are being explored with plots and production-scale plantings in every continent.

Wild ruminants and other large herbivores in desert areas are few in terms of both species and individuals. Some of the same species occur that inhabit savannas, and herds from wetter areas migrate into deserts during wet seasons. Game ranching and harvesting in the desert appear unattractive because of low carrying capacities. Large areas with no free water for drinking appear to be the major reason for so few large mammals. This might be inferred from the fact that the desert gazelle, desert oryx, gemsbok, ibex, and others survive on metabolic water with infrequent drinking, and most have physiological processes that restrict loss of water. Desert-dwelling species have suffered as a result of hunting from automobiles and from habitat change, as have herds in other climates.

In grazing economies where wildlife live with domestic livestock, careful attention must be given to stocking rates of all animals to prevent overexploitation of vegetation and soils. Excessive competition between large mammals, domestic or wild, is devastating to the production of both. Rangeland resources may be impoverished in the process.

Seasonally Flooded and Wetland Vegetation

Vegetational and soil maps of all countries and larger regions often do not show, because of scale, places where the soil may be seasonally flooded or at least saturated for the full length of the wet season. These areas with impeded drainage are small, often linear, and occur in poorly drained depressions, along streams and borders of lakes. Seldom do descriptions, inventories, and larger-scale maps of project areas give much attention to these special habitats. Although contributing no more than 1% of the rangeland, they produce an unknown but far greater forage value because more biomass and plants remain green after the upland forages are dry. Both wild and domestic animals tend to concentrate on these habitats during dry seasons. Seasonally flooded or wet habitats occur within all major rangeland vegetational types and contribute greatly to animal well-being.

Several extensive wet areas are well known, such as those along the Nile and Niger Rivers in Africa and the Amazon in South America, the swampy forests in Brazil and New Guinea, the depression in the plains of India, and the Sudd in the southern Sudan. Southern and southeastern Asia, northern Africa, and northern Australia support many water buffalo on wetland grazing. Seasonally flooded grasslands in the llanos (open, grassy plains) of Colombia and Venezuela are the habitat of the capybara, a large rodent harvested for meat on a regular and managed basis.

The soils of these wet habitats are usually high in clay that is gray, bluish, or brownish; plastic or sticky when wet; hard when dry; and through which water moves very slowly. They are known as black cotton soils or dark, cracking clays high in montmorillonite. They occur in all regions of the tropics and temperate zones with rainfalls above 200 mm from desert oases to tropical rain forests and from sea level to areas surrounding springs in boreal forests. They are of great importance in savannas and forests, and are known locally by such names as mbugas and dambos in Africa and esteros in South America.

Vegetation is as varied as the location and soil. Waterlogging tends to decrease trees and increase tropical grasses and grasslike plants. Swamps in the African tropics have stands of papyrus *(Cyperus papyrus)*, reeds *(Phragmites communis)*, bulrushes *(Juncus* spp.*)*, and sedges *(Carex* spp.*)*. Colombian esteros support *Leersia hexandra, Hymenachne amplexicaulis*, and *Paspalum fasciculatum*. These plants are 2 m or more tall where seasonal flooding lasts the longest. Palms sometimes are the only trees in this habitat; examples are *Copernicia tectorum* in South America and *Borassus aethiopum* in Africa

On seasonally flooded habitats in Africa where the substrate has silt and sand mixed with the clay, one is likly to find *Vossia cuspidata, Oryza barthii*, and *Echinochloa* spp. in successive zones from the wettest toward the driest sites. The center zones of these wet habitats usually do not burn when fire sweeps surrounding vegetation. The black-cotton-soil habitats of East Africa support *Cynodon* spp. and *Brachiaria* spp., while those in northern Australia have stands of the tree, *Bauhinia cunninghamii*, and a grass understory dominated by species of *Sorghum, Sehima*, and *Chrysopogon*. Montane wet-meadow vegetation, nearly everywhere it is found, will be dominated by *Poa* spp., *Agrostis* spp., and *Carex* spp.

In most cultures these wet areas are saved for dry-season grazing for three reasons: The sticky wet soils promote trampling damage, the forages are of higher quality than surrounding upland feeds in the dry season, and biting flies may be troublesome in the wet season. Examples include live-

Figure 6. *The deciduous trees and abundant grass grow on a black soil that is high in clay. It is waterlogged during the wet season (photo taken in Uganda).*

stock congregating on the marshes bordering Lake Chilwa in Malawi and game animals moving toward permanent water during the dry season. The subsistence farmer with a few livestock is often vitally dependent on the seasonally wet rangelands near his crops. Wetlands offer the best feed in the late dry season. They are near home and can be used in conjunction with crop residue late in the dry period. If livestock are allowed to use the wet areas before nearby crops are harvested, they will be less tempted to trespass on the crops. Careful herding and proper plant utilization of the wetland vegetation are to be encouraged.

Vegetation types in swamps and riverine situations, and on soils with impeded drainage are difficult to manage. The areas are small, often narrowly linear in shape, and highly attractive to animals during the dry seasons. If the animals are left alone, the areas near water will be overgrazed while the upland vegetation remains underused. Fencing is expensive and not practical in small areas or in developing economies. Fortunately, many of the plant species are resistant to heavy grazing, but they too can be damaged by continued severe defoliation. Favorable soil moisture provides the opportunity for seeding, but the species must be selected with attention to wet- and dry-season adaptations. Drainage may be increased by trenching. In other situations, the clay soils in basins may be of advantage in building structures for water storage.

Tropical Rain Forests

Tropical rain forests are also called humid forests and wetland forests. The vegetation is a complex of many species, often forming a tangle of plant materials from soil surface to tree tops as much as 60 m above the ground. Rainfall is generally more than 1500 mm/yr and may be four or five times that amount, but most of these forests receive less than 2000 mm/yr. Their equatorial location results in a constantly moist and warm climate with little or no dry season. Clearing increases air temperatures near the ground because of reduced shade. The principal forests in this category cover about a third of the tropical landmass including the Amazon basin, Central America and Caribbean Islands, Congo basin, coastal West Africa, southeast Asia, southwestern Pacific islands, and parts of northern Australia.

Tropical forests vary from frequently flooded and waterlogged soil to monsoonal humid evergreen forests with a short dry season. Little ground vegetation can be used by ruminants. Domestic animals, except the pig, and large wild animals are few. Small ungulates such as duikers, bushbucks, wild pigs, members of the deer family, and pygmy hippopotamuses may be present. The coldblooded animals are abundant in species but not in numbers per hectare.

Mangrove vegetation occurs on the tidal mudflats along many tropical shores where fresh and salt water mix. Contrary to widely held impressions, the vegetation is a mixture of many species of trees and shrubs. Cattle of the *Bos indicus* type, water buffalo, wild pigs, and key deer are principal grazers and indicate that grazing management has a place even in the mangrove forest. In the Middle East, Pakistan, and

India, mangrove foliage provides good quality feed for camels and cattle during the dry season, and in addition supplements their mineral intake with salt, iodine, and several trace minerals.

Figure 7. *Borassus palms and grasses on a seasonally flooded site in Tanzania.*

In undisturbed conditions, only a small percentage of the precipitation becomes runoff and little geologic erosion takes place. When cleared, the soils become highly erodible until secondary succession returns a protective cover. Because precipitation of several inches comes every month, clearing at any time of the year can be damaging. After clearing, more than 25% of the precipitation may become runoff.

Water balance (the division of precipitation among evaporation, discharge or runoff, groundwater reserve, and transpiration) differs greatly among the range ecosystems. Continental water balance in map form by Baumgartner and Reichel in 1975 shows the following relationships on the basis of precipitation equaling evaporation and discharge (table 1).

Table 1. *Water Balance Relationships For Selected Rangeland Systems*

	Precipitation (mm)	Evaporation (mm)	Discharge (mm)
Savannas with tall grasses	350 - 700	350 - 700	0 - 75
Deciduous forests with high grasses	700 - 1500	700 - 1200	75 - 300
Desert shrub and grasslands	20 - 350	350	0
Tropical rain forests	>1500	1000 - 1400	100 - 1200

Additions to groundwater reserves and transpiration were combined with discharge and evaporation in the above table because of few data. However, tropical rain forests are of major importance to project planning and rangeland development. The above table shows that the deserts and drier grasslands have little or no discharge of water and that the major rivers are fed from precipitation on the forests and woodlands. Locally, water balances will change according to the vegetational changes. Trees and grasses intercept rainfall and transpire water. As management reduces the height and area of plant surfaces, and to a certain extent biomass, less water is evapotranspired and more goes to groundwater and discharge. In project planning, attention should be given to the impact of development on water balance and its close relative, erosion.

The tropical humid forests are the major regions of shifting cultivation. When the forests are destroyed, the nutrients stored in the woody materials are released. Some are used by the cultivated crops but many are lost, causing crops to fail and farmers to clear new land. The early plant successional stages following abandonment of cultivation include numerous grasses and forbs that can be feed for animals, but shrubs and young trees will dominate within approximately 5 years. These grazing resources are closely associated with cultivation and forestry, hence the need to consider tropical rain forests with the more conventional rangeland ecosystems and with agroforestry.

Grassy glades within and near the African rain forests will nearly always have *Loudetia simplex*, *Pennisetum purpureum*, or *Imperata cylindrica* in abundance. After clearing, *Imperata* is spontaneous and can succeed *Pennisetum* if that genus should dominate first. Three species of *Hyparrhenia (H. cymbaria, H. diplandra, H. rufa)* will be on different sites due to slope and drainage. Following clearing of moist forests of Madagascar, the vegetation is *Ericoid* brush and *Aristida* grassland.

Forests in southeastern Asia are somewhat open and are probably subclimax to the rain forest due to shifting cultivation, grazing, and fire. The dominants are *Dipterocarpus tuberculatus*, *Pentacme suavis*, and *Shorea obtusa*, and their dominance extends over 40% to 50% of the region. The other half is mostly cultivated.

Teak *(Tectona grandis)* is another important species. The dense forest has stands of *Heteropogon triticeus*, *Arundinella setosa*, and the dwarf bamboo, *Dendrocalamus strictus*. Grasslands in wet areas will largely be *Echinochloa*, *Phragmites*, and *Saccharum;* and *Imperata*, *Sorghum*, and *Themeda* on drier ground nearer the forest edge. These types are virtually the same throughout the region, where native cattle, koupreys *(Bos sauveli)*, bantengs *(Bos banteng)*, and gaurs *(Bos gaurus)* may still be found.

A worldwide grass species in tropical forest openings is *Imperata cylindrica*. It is an active invader, a difficult competitor of crops and planted forages, and avoided by grazing animals (except for the tender leaves immediately following fire). *Imperata* may be replaced by *Hyparrhenia rufa* in the American tropics as the native soil fertility is regained; some consider this a time to recultivate. Improvement in soil fertility for crops, planted trees, and forages depends largely on leguminous trees that also provide wood and human foods. The forage legumes, such as *Desmodium*, *Centrosema pubescens*, and *Stylosanthes* spp. aid materially in increasing grass production from the planted *Pennisetum purpureum* and *Panicum maximum* and in improving the nutritional qualities of the feed. These legumes even increase livestock acceptance of *Imperata*.

Vegetation in Winter Rainfall

This vegetation type is commonly called the Mediterranean type of combined woodland, shrubland, and grassland. It is found in a climate that is characterized by cool, wet winters alternating with hot, dry summers. In addition to northern Africa, southern Europe, and the Middle East, it occurs between 30°N and 40°N, and 30°S and 40°S on the west side of southern Africa, in North and South America, and in Australia. It is only marginally subtropical.

It includes the olive, oak, and pine forests of all coasts of the Mediterranean Sea; *Proteaceous* and *Ericaceous* shrubs of southwestern Africa; legumes, succulent cacti, and shrubs in Chile; oak, ceanothus, manzanita, and pine in western North America; and eucalyptus in the southwestern corner of Australia. Many of the shrubs and trees are evergreen and have small, narrow leaves. The grasses are typically annual, germinate from seed with the first rains in the autumn, and shed

Figure 8. *Oak trees and annual grasses in the winter-rainfall area of California.*

their seed as they dry in the spring. They form a thick, protective soil cover. Grassland islands within the shrublands often indicate previous fire. Broad-leaved flowering herbs dominate the first year after a fire, and shrub dominance returns in 10 to 15 years. Some conversions of thick forest and shrub stands to scattered shrubs and grasslands have been partly successful through the repeated use of prescribed fire.

Vegetational type conversions from shrubs to grasses in these ecosystems have given mixed hydrologic results. Some have increased runoff as much as 50%, but others have shown decreases in runoff. The hydrologic success or failure of treatment depends on pretreatment cover conditions and posttreatment cover and management. Depending upon the situation the goal may be either more or less water runoff.

On fertile soils the grasses can produce as much as 6 t/ha. Planting of annual legumes in the genera *Trifolium* and *Medicago* and fertilization are common practices in intensively managed Mediterranean annual grasslands. Nutritive quality is low during the dry season but moderate use allows animals to select the best parts of the herbage and to browse from trees and shrubs. A managerial objective for combined grazing and browsing by domestic and wild animals would be a mixture of grasses and shrubs with each contributing half the cover. The shrub patches should not be more than 3 m or 4 m in diameter. Since shrubs are prolific seeders and sprouters, it takes repeated fires to open the shrub stands for more than a few years. More understanding of grazing management techniques is needed where timber trees such as *Pinus radiata* have been planted because the trees soon crowd out the understory. With care and management, trees and forage can be raised on the same land in the Mediterranean-type climate.

Montane Forests

Less than 5% of the tropics support montane or temperate forests. These areas, mostly above 1800 m elevation, are found in Ethiopia, the Kenya highlands, the Andes Mountains in South America, Indo-China, New Guinea, and the Himalaya Mountains. An additional 15% of the tropics lie between 1000 m and 1800 m and support highland forests. Descriptions of highland and montane forests and associated vegetation that cover portions of North America, Europe, and Asia are omitted because the emphasis is tropical in this paper.

Tropical highland forests are complex mixtures of tree species in contrast to many temperate forests where only a few species dominate. These forests have a thick mostly evergreen canopy and a thin understory of shrubs and herbs. Successional stages of various ages are scattered throughout, indicating former fields in shifting cultivation that are returning to forest. Grasslands within and elevationally above the forest in Kenya are composed of species from the tropical genera *Pennisetum, Eleusine,* and *Panicum;* and also from the typically cool-temperature genera *Poa, Bromus, Festuca. Trifolium semipilosum,* which grows in the highland meadows of Kenya, is similar to *T. repens* of temperate regions.

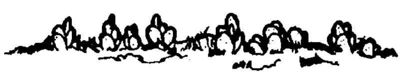
Figure 9. *Montane forests and cool-season grasses in a mosaic of vegetation in the Kenya Highlands.*

Montane forests influence all portions of the hydrologic cycle. Interception and transpiration losses by trees may be significant, and infiltration rates permit abundant groundwater recharge. Larger hydrologic impacts result from removing trees than from reducing grasses. Poorly constructed roads result in much runoff and erosion.

A widespread genus of coniferous trees *(Pinus)* with many species growing in montane forests commands great interest as commercial timber in the tropics. Several species have been successfully planted far beyond their native habitats. Of note is *Pinus radiata*, native of the winter rainfall coast of the western United States, which is now grown in plantations as widely separated as the Philippines, Kenya, and New Zealand.

Many native montane forests and tree plantations furnish forage for livestock, especially during the establishment period before the tree canopy closes. In addition to the forage produced, there are benefits to the trees including less competition from grasses and weeds and less fuel, hence less fire hazard. Damage to trees by livestock has been slight in most research trials and difficult to separate from that caused by wild herbivores, insects, and disease. Managed forest grazing by domestic and game species in native forests and closely tilled tree plantations has been practiced for 100 years in Europe and the United States. Its recent rise in popularity as agroforestry, where crops, trees, and forage are grown together, promises further development in the tropics. Grazing is an important element in land development from deserts to high elevations and humid forests in the tropics.

Table 2. Key Characteristics of Major Tropical Rangeland Systems.

Systems	Length of Dry Season	Type of Grazing	Cattle per Person	Animals/ km^2	Site Potential	Agroforestry
Savannas with tall grasses 	6-9 mo.	Transhumance and village based	6-15	25, all domestic species	Low to high	Semiarid trees — mostly legumes
Deciduous forests with high grasses 	3-6 mo.	Transhumance and village based	1-4	15, all domestic species	High with seeded legumes	Wide range of possibilities
Desert shrub and grasslands 	9-12 mo.	Nomadic	0-4	10, mostly camels and goats	Low except with water harvesting	Local leguminous shrubs and trees
Seasonally flooded and wetland vegetation 	NA	Seasonal use	NA	NA	High	Slight possibility

Systems	Length of Dry Season	Type of Grazing	Cattle per Person	Animals/ km^2	Site Potential	Agroforestry
Tropical rainforests 	<3 mo.	Sedentary	±1	<5, all domestic species	High with legumes	Local species
Winter rainfall vegetation 	5-7 mo.	Yearlong	6-15	10, all domestic species	High with legumes	Coniferous trees
Montane forests 	<5 mo.	Yearlong	NA	>25, on improved pastures of temperate species	High with legumes	Coniferous trees

Annotated Bibliography

Baumgartner, A. and E. Reichel. 1975. The World Water Balance. Elsevier Sci. Pub. Co., Amsterdam. 179 pp.

Written in two columns, one in German and one in English, the world, continental, and regional supplies of fresh water are described on the basis of tables and maps showing precipitation, evaporation, and discharge.

Bourliere, F. 1983. Ecosystems of the World. Number 13: Tropical Savannas. Elsevier Sci. Pub. Co., Amsterdam. 730 pp.

This book has 31 chapters and 28 contributors, of whom 11 are French. The book describes and reviews the ecological research on most components of the savanna ecosystem that lies between deserts and humid forests. Its coverage is in as much detail as the information permits. Discussions of land and animal management are not included. Literature citations are extensive.

Heady, H. F. 1985. Forest Grazing Management: Guidelines for Agro-Silvo-Pastoralism. (In press.)

This is a review of the worldwide literature on agroforestry with emphasis on grazing. Over 1000 publications were searched and about 140 cited. Chapters are on vegetational types, pastoral systems and customs, grazing management, planning for development, and institution building.

Keay, R. W. J. 1959. Vegetation Map of Africa. Oxford Univ. Press, Oxford. 24 pp.

The Yamgambi Vegetational Classification Scheme of 1956 as revised by Keay is accepted by many as the best for Africa. It is small scale and more useful for country and regional planning than for project analysis.

United Nations Educational, Scientific and Cultural Organization (UNESCO). 1979. Tropical Grazing Land Ecosystems. Natural Resources Research Series 16. UNESCO, Paris. 655 pp.

This large book describes tropical ecosystems in terms of floristic composition, climate, water, soil, erosion, and biomass turnover. Over half the pages are devoted to socioeconomics of tropical ecosystems, and a number of case studies are described.

Chapter 2

Peoples

The characteristics of rangeland peoples that influence, or even control, rangeland development are highlighted. The importance of focusing development toward the holder of subsistence mixed farming and of subsistence grazing is emphasized because 50% of the land of the world is rangelands, and millions of people live on it. Little is given on the previous development efforts toward large-scale country commercial projects. This change in emphasis results in more attention given to people's livestock management techniques rather than their statements about livestock; to their traditional production systems rather than their statements about their beliefs; and to social customs on land tenure, diet, household economies, and demographic characteristics. This chapter attempts to describe these characteristics and practices as they should be considered for rangeland planning. The goal is to aid the gathering of data that encourage project developers to work with indigenous peoples, not simply for them.

Traditional Rangeland Use

The human experience on tropical rangelands has a long history. This history has produced a wide variety of adjustments by rangeland vegetation and soil that are related to localized environmental circumstances or human modifications of them, and also to different and often changing cultural beliefs and values. Indeed, no sooner than did tool-using *Homo sapiens* emerge as the dominant species and user of fire than did both the character and extent of savannas and grasslands become dependent on his land-use practices.

Hunter/Gatherer Societies

For most of human history, a hunting/gathering, subsistence economy has been the predominant form of rangeland use, particularly in Africa. This greatly influenced subsequent types of land-use practices that followed. Small, highly mobile hunting/gathering bands of families communally organized by kinship ties tended to thrive mainly in the interface areas between dry forests, open grassland plains, and the savannas described earlier. Dependent for survival mainly on the gathering activities of their women for fruits, nuts and berries, honey, insects, and small animals, such bands developed distinct adjustment strategies to cope with highly variable patterns of seasonal aridity. Through deliberate or accidental use of fire they gradually began to expand upon and greatly modify or extend the grasslands themselves. Foremost among their adjustment strategies was the cultural emphasis given to communal resource exploitation and sharing, based on strong beliefs concerning egalitarianism between cooperating families and on the need for individual commitment to equity and austerity ethics. These values still characterize many traditional rangeland peoples.

Among the more important legacies of this long hunting/gathering tradition is a highly detailed and extensive knowledge of the physical environment. Such knowledge includes, for example, the food value, toxicity, or medicinal properties of a wide variety of plants and the growth, dominance, and climax characteristics of particular species. These often signal important ecological changes in an area. Some cultures have extensive systems of plant naming and classification. More importantly, they have knowledge of and experience with locally available resources that frequently are not perceived as "resources" or food by outsiders, who approach rangeland management with entirely different ideas of appropriate land use. For instance, honey collecting and the semidomestication of bees in strategically located homemade hives have provided a significant food or energy source for both hunting /gathering peoples and many of the pastoral societies who followed them. Beekeeping seldom is given any attention in modern rangeland-development schemes.

In recent years, pure hunting/gathering economies have largely disappeared throughout most tropical rangelands, mainly as a result of national policies favoring wildlife conservation and new ideas from governments about appropriate cultural development. But the hunting/gathering peoples themselves have not vanished, nor has their rich knowledge about local environmental resources and processes. Many rangeland families are direct descendants of formerly autonomous hunting/gathering peoples. Their ecological knowledge and skills play an important role in the successful use of land under new management practices, such as pastoralism or subsistence farming, into which they have now been ethnically and practically absorbed. Indeed, some so-called traditional pastoralists, such as the Okiek of Narok District or Mudogodo of Laikpia District, Kenya, have changed from basically hunting/gathering peoples to become more or less full-time pastoralists only within the past two or three decades. Their mode of livestock production not only differs greatly from that of their pastoral Maasai neighbors, but many of their practices contribute significantly to the success of the Maasai. In short, the long-standing, expert knowledge of local ecological dynamics possessed by the people is itself a valuable rangeland resource that should not be overlooked by development planners or researchers.

Domestic Livestock of Rangelands

Introduction of domestic livestock into tropical rangelands occurred at least 5,000 to 6,000 years ago, first as a supplement to hunting and gathering, then later mainly as a replacement for it. In Africa, for instance, archaeological evidence from 4,000 years ago reveals a number of livestock-keeping sites scattered within a crescent ranging from West Africa through the Sudan into East Africa. Although in recent centuries many pastoral production systems have given cultural emphasis or preference to the keeping of large ruminants such as cattle or camels, it would appear that most traditional pastoral systems depended for their development and existence on the keeping of sheep and goats as well. Indeed, not only has the role of small ruminants in maintaining the total production system of pastoralists been inadequately appreciated or understood by most development planners, but in many such systems it is doubtful whether cattle or camel production could in fact be sustained in the absence of an integrated multispecies approach to livestock production.

By 1500 B.C. (or 3,500 years ago) numerous full-scale, culturally distinct pastoral societies had established themselves throughout most of the savanna grasslands, except for southern Africa. Some continued occasional hunting and even fishing activities in conjunction with their increasing livestock dependency. But the fossil remains of a high percentage of adult milk cows at particular archaeological sites, such as Narosura in Kenya, suggest that other prehistoric pastoralists had already developed distinctive milk-drinking subsistence practices at least as early as 3,000 years ago. Although there is also indirect evidence of food gathering at some sites, there is little or no indication of agriculture or domesticated plants. In the case of the eastern African interior, pastoralism predated the emergence of agriculture by at least 1,000 to 2,000 years. The same is suspected for other areas of Africa. The epicenters for early pastoral development appear to have been located entirely in the northern tropical rangelands (e.g., the Sudanic region, and the rangelands of West and East Africa) and to have diffused southward only within the last 2,000 years. This slow spread of pastoral systems into southern and central African rangelands is due partly to the presence of trypanosomiasis and other epizootic diseases, which have always been an important barrier to the spread of livestock into the deciduous forests of Africa.

The Rise of Tropical Agriculture

Agriculture is believed to have originated in several of the northern savanna/forest border areas of Africa as early as 3000 B.C. Initially, it spread southward into the deciduous and then tropical rain forests. It was not until the several centuries immediately before and after the birth of Christ that any appreciable cultivation of food crops began to appear in the pastoral rangelands of Africa. The first crops consisted mainly of indigenous millets and sorghums. In most instances, the cultivation of crops was associated with the relatively rapid spread of iron-working and the emergence of long-distance trade networks throughout Africa. Except for scattered settlements or trade centers closely related to metallurgy and other developing craft industries, overall agricultural development on the rangelands tended to be tentative, uneven, and highly variable. There is abundant archaeological evidence of initial expansion and then contraction of agriculture in many areas. At some locations like Engaraka in Tanzania, agricultural economies using irrigation emerged on rangelands for a century or two and then disappeared altogether.

Mixed Farming Versus Pastoralism

The rise of tropical agriculture during the past two millennia did, however, set in motion several distinct cultural trends that have come to characterize rangeland development ever since. First, together with metallurgy, a shifting slash-and-burn (swidden) agriculture began to spread rather quickly throughout the deciduous and tropical rain forests. This not only opened the canopy and allowed increased cultivation and human population expansion, but it also reduced the incidence of tsetse fly and trypanosomiasis. This facilitated the spread of livestock into southern Africa, mainly in the form of "mixed farming." As agricultural populations increased, mixed farming also expanded into the rangelands. Some pastoral societies incorporated shifting agriculture into their pastoral economies as a supplementary activity to reduce their dependence on hunted or gathered foods. Others engaged in a regular exchange with neighboring settled cultivators, trading livestock products for portable agricultural foods.

Secondly, the rise of agriculture increased economic specialization and subsistence variability, both within and along the fringes of the rangelands. There emerged at the same time a great deal of cultural variability or ethnicity, which began to express itself in the form of distinct food preferences or dietary prohibitions. For example, some rangeland peoples began to assert their cultural identity and social separateness by developing strong prejudices against eating wild animal foods, such as fish or fowl, a trait still common to many rangeland societies. Others developed similar cultural aversions to either growing or eating agricultural foods. They depended mainly on raising livestock either to exchange for occasional agricultural foods or by attempting to subsist more or less completely off livestock products. Particular systems began to vary culturally, depending on the extent to which subsistence was based on wild foods, pastoral foods, or agricultural foods, and what combination of them. Additional variability occurred in terms of cultural use -- e.g., whether livestock were raised primarily for meat, milk, trade, or to fulfill social obligations; and whether preference was given to the keeping of cattle, camels, sheep, or goats, and in what combination or for what uses.

Thirdly, partly as a result of the rise and expansion during the first millennium A.D. of various agriculture-based kingdom states and trading empires, market centers and trade routes began to develop along the fringes of and within various tropical rangelands. This happened particularly in the Sahel region of West Africa, northern Sudan, and the Horn of Africa. Some rangeland societies quickly became involved with such centers and developed a distinct market-orientation to their economy, while others tended to avoid them. Hence, together with other areas in which external trade was not significant, two distinct types of resource-use systems began to emerge in the rangelands during the past millennium: 1) those with a long history and relatively high degree of interaction with and market-dependency on neighboring settled agricultural systems, in which livestock were raised and traded partly for other preferred agricultural foods and 2) those relatively autonomous systems with little or no external market-orientation or dependency, in which livestock were raised almost exclusively for subsistence and social exchange.

The pastoralism of the Fulani, Tuareg, Baggara, Bedouin, or Somali, for example, is traditionally highly market-oriented. In addition to livestock, they also marketed other range products such as salt, honey, medicinal herbs and plants, exotic woods and aromatic gums (e.g., frankincense, myrrh), ivory, and other wild animal products. Their current practices and development problems cannot, therefore, be understood adequately without consideration of their close interaction with settled agricultural communities which, whether located outside or within the rangelands proper, form part of their total resource-use system. This interaction involves elaborate exchange networks, often based on various traditional patron-client relationships, that are crucial to both the operation and understanding of how the system works.

The subsistence pastoralism of such peoples as the Boran, Maasai, and Turkana of East Africa, on the other hand, poses distinctly different problems for development related not only to the relatively large numbers of people supported directly in the rangelands by their livestock subsistence practices, but also to the fact that their resource-use system has little or no involvement with external market exchange. The creation and maintenance of external exchange networks is itself a crucial development problem among pastoralists of this type. Other rangeland systems developed in differing degrees between these two polar extremes, some even fluctuating over time depending on local climatic, physical, or sociopolitical environmental changes.

Finally, with the advent during the last century of colonialism, European settlement, and national independence, some tropical rangelands were converted to commercial, single-family-ranching or mixed-farming systems, based on the introduction of freehold title and enclosure of land. Others were designated as wildlife reserves or national parks in which traditional resource uses, such as hunting/gathering or pastoralism, were prohibited. In most cases, this was done both at the expense and to the detriment of existing traditional systems, many of which lost huge areas of their more favorable range and water resources to European settlement and to the encroachment of indigenous agricultural squatters who often followed them. Indeed, few events in the long history of tropical rangelands have had a greater impact than the fairly recent attempts to transform them through the application of principles and techniques of commercialization. This process has few historical precedents in the tropical rangelands. The result is that most traditional systems still are adjusting to the imposition of commercialization by attempting to develop responses compatible with the importance they still attach to communal resource use.

Commercial Versus Traditional Production Systems

The response of traditional pastoralism to national and international pressures for increased commercialization has taken many forms, depending on local political and economic circumstances and induced-development efforts. Briefly, such responses tend to occur along a continuum based on large-scale commercial ranching efforts at one end and small-scale traditional pastoralism or mixed farming practices at the other. Individual ranches, company ranches, and ranch cooperatives tend to cluster at one end of the continuum, representing distinctly modern commercial production systems. Smallholder subsistence pastoralism exemplifies the traditional rangeland use. Various forms of grazing associations, grazing blocks, group ranches, or other development schemes tend to lie somewhere between, but are based more on traditional smallholder subsistence strategies than on commercial practices.

In Kenya, for example, only 25% of the national rangeland cattle herd exists in commercially oriented, individual, and company ranches. Indeed, 75% exists in either underdeveloped group ranches (35%) or grazing associations (15%), or in essentially unchanged traditional, subsistence production systems (25%). Close to 78% of Kenya's rangeland sheep and goat population exists in traditional production systems (Bernsten and Jacobs, 1983). Data from other developing nations are scanty but suggest even higher proportions in the traditional systems.

A broad range of fundamental differences in rangeland management principles and social practices characterize the distinction between commercial ranching and traditional subsistence pastoralism. Efforts to modernize or commercialize traditional production systems must, therefore, take account of these differences when considering particular development interventions or priorities. This is because what may appear to be good management practices in one type of livestock production system, say commercial ranching, are often incompatible or unworkable in the operation of another system. Some of the major differences between commercial ranching as a total production system and traditional pastoralism are as follows:

Commercial Ranching

Implicit in the notion of "ranch" is the cultural value that private property is necessary for economic efficiency. The emphasis in commercial ranching is on grazing-block management, in which the land is often fenced to exclude wild ungulate competitors as well as human trespassers.

Commercial ranching is also a distinctly land-oriented, market-dependent management system that is organized primarily to satisfy outside consumers living mainly in urban centers. Land value appreciation is often a more important actual component than are the livestock products. The ranch cannot be increased by investments of the herd/flock products except through elaborate economic institutions that facilitate conversion of products to cash. Expansion depends mainly on new land purchases. Commercial ranching is mainly a specialized form of cropping in which resource use is perceived and organized differently than it is by traditional pastoralists. For example, commercial ranch output is measured mainly in terms of fixed-time quotas of livestock units rather than in terms of the numbers of people actually supported directly by the system.

Traditional Subsistence Pastoralism

In sharp contrast to commercial ranching, smallholder pastoralists place great cultural value on communal forms of organization and public control of range resources. Such communalism is viewed as a necessary response to highly variable droughts that tend to dominate rangelands, and to fluctuating herd movements. They also consciously pursue communal goals of cooperation and sharing in order to assure equity and distribution of wealth, which they see as the only possible response to their harsh environment. Some subsistence pastoralists, especially in East Africa, coexist with large densities and varieties of wildlife. Other pastoral subsistence systems often tend to exploit wildlife resources in a more competitive manner, supplementing mixed farming with wildlife products for food or trade.

Traditional subsistence pastoralists are livestock dependent, with livestock ownership and subsistence being an explicit strategy for maintaining the largest number of people under difficult environmental conditions. Their basic investment capital is livestock. Hence, herd/flock savings and investment are essential; the accumulation of large surpluses is necessary to survive drought. Unlike commercial ranching, such investment is possible without external economic institutions, since the main product of the herd/flock is offspring and not cash. This is an important factor in their alleged resistance to change and to the problem of integrating subsistence pastoralists into more commercial systems.

In subsistence pastoralism there is characteristically a low ratio of livestock to human beings. Moreover, output efficiency can be measured in terms of human rather than livestock units, and each group's survival measured mainly in terms of human nutrition, health, growth, prosperity, etc. Thus, a "wealthy" person in such systems is generally defined as one with many healthy children rather than one who simply owns many livestock.

In contrast to commercial ranching, much greater emphasis is given in traditional pastoralism to multiple-species livestock production. This commonly involves family management of large numbers of small ruminants as well as cattle, camels, or donkeys. Such diversification not only increases the range of resource use, but also spreads the risk of livestock losses and permits the entire family to be used for labor inputs. Similarly, multiple livestock products such as milk, meat, blood, hides and skins, and animal power, are available. Human energy and labor-intensive investment, rather than fossil fuels and complex tools, remain the principal components of such systems.

Characteristics of Rangeland Peoples

Development and People

In order for systems -- human, biological, or mechanical -- to sustain or progressively modify themselves, they must be able to adjust or change their components. For this, each system may be said to behave according to a model or code, which in effect serves as its guide.

In most rangeland areas of the tropics, particularly in East Africa, the successional pattern of grasslands without human intervention is normally one that is giving way to a dry forest/thicket climax. When these tropical rangelands are inhabited and manipulated by people and their domestic animals, such change does not necessarily occur. This is because the successional pattern is dominated by the practices of its human inhabitants, and the complex social systems that they have constructed.

Thus, the key to appropriate and effective development of rangelands lies in understanding the aims, purposes, and goals of its human inhabitants. Modifying such systems involves introducing models of integrated resource use that provide advances that the people themselves can measure. In short, development strategies for rangelands must be socially as well as ecologically sound in order to succeed. They must also fulfill the regulations of the donor countries.

One of the most important factors affecting the possibility for successful development of rangelands is innovation in the planning process. Not only must plans make sense for particular local situations, but they must also be based on explicit social theories or hypotheses as to how and why a particular intervention is likely to succeed. Indeed, only when development plans that incorporate such theories are consciously formulated and tested, and the implementation process is open to discussion and criticism, can one hope to identify those factors contributing to success or failure -- and thereby gain useful criteria for choosing between alternative interventions.

For example, some of the more important social concepts that have been tested and found to be valuable in development strategies are the following (Jacobs, 1972):

- Successful development depends on planning with people, not for them. The recipients must be equal partners in the planning and implementation process in order to help identify appropriate and relevant interventions, and to ensure favorable results.

- Development must capitalize in large part on the expressed social or technological needs of the people concerned. Correspondence between the innovation proposed and the needs felt by the people concerned is often one of the most important factors contributing to the acceptability and success of an innovation.

- Nothing ever happens exactly as intended. Hence, systematic monitoring both to correct unwanted consequences and to help identify successful procedures or trends is essential.

- Small-scale, limited-purpose interventions are more likely to succeed immediately than large-scale, multipurpose interventions. That is, the larger and more complex the innovations, the greater are the problems of implementation and the more difficult it is to identify and correct unintended consequences, as well as to identify the precise causes of success, or failure.

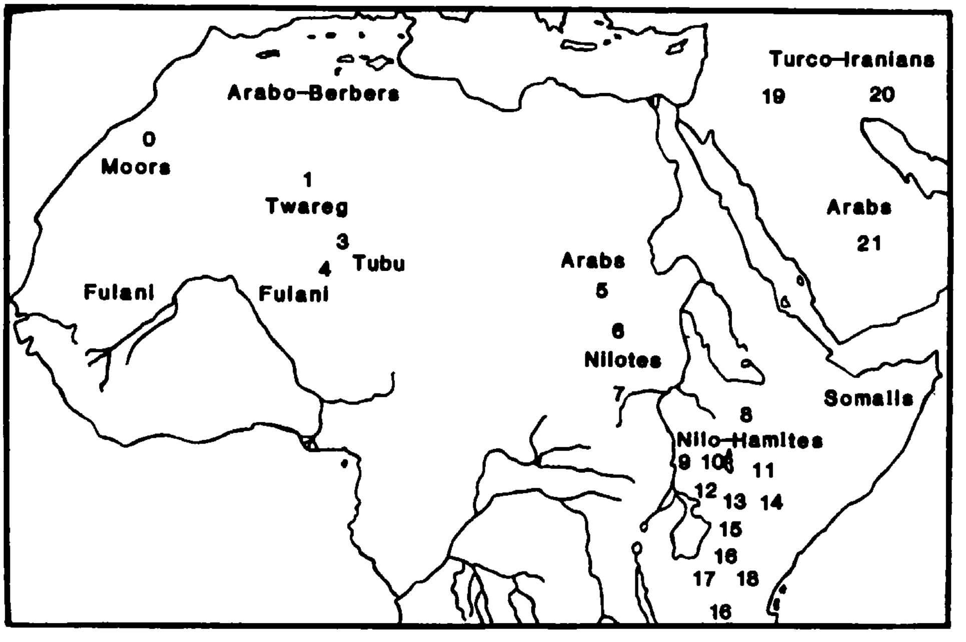
- Because technological solutions do not exist in isolation, but are embedded in complex social behaviors and institutions, the ultimate success of an innovation may depend less on the merits of new techniques or technology than on the effective introduction of new modes of social organization or administrative control necessary to make them work.

- To promote success all development plans must incorporate short-term proofs of effectiveness or benefits -- even if the ultimate aim is long term. Innovations that demonstrate clear and immediate evidence of effectiveness are more likely to gain rapid and widespread acceptance than are plans based only on long-term benefits.

The above concepts illustrate the need for an approach directed toward understanding the logic and operation of local production systems. This entails not only determining the conditions of the local physical and biological environments (i.e., the natural environment or resource base), but also the range and types of social goals, institutions, and behavior that guide people locally in coping with or adjusting to their natural resources. Local systems are normally parts of larger production systems involving regional or national interactions. Local perspectives are a better guide to predicting the consequences of, or scope for, particular changes than are the perspectives of outsiders (Galaty et al., 1981).

Population

Of the 500 million to 600 million people estimated to be inhabiting the arid or semiarid tropical and subtropical regions of the world, some 30 million to 40 million people (approximately 8%) are believed to possess "livestock-dependent" economies. These livestock-dependent people will be referred to as pastoralists. Some 20 million (55%) are in Africa, 10 million (29%) in Asia, 5 million (15%) in the Americas, and less than one-half million (1%) in Australia. Figure 10 and table 3 summarize some of these societies' characteristics and geographical locations. In Africa, the countries with the largest number of pastoralists (in descending order) are Sudan, Somalia, Chad, Ethiopia, Kenya, Mali, and Mauritania -- each of which possesses 1 million or more pastoralists, including men, women, and children (Sandford, 1983). Due to limitations on the uses to which most rangelands can be put and constraints for alternative employment, it seems reasonable to assume that most present "pastoral" areas will remain so, and that many millions of people -- especially in Africa -- will continue to practice some form of pastoralism.



0	*Reguibat*	*12*	*Karimojong (Uganda)*
1	*Kel Ahaggar Twareg (Algeria)*	*13*	*Pokot (Kenya)*
2	*Kel Adrar Twareg (Mali)*	*14*	*Samburu (Kenya)*
3	*Kel Air Twareg (Niger)*	*15*	*Nandi (Kenya)*
4	*Sahelian Twareg*	*16*	*Masai (Kenya, Tanzania)*
5	*Kababish (Sudan)*	*17*	*Barabaig (Tanzania)*
6	*Baggara (Sudan)*	*18*	*Arusha (Tanzania)*
7	*Nuer (Sudan)*	*19*	*Rwala (Syria)*
8	*Galla (Ethiopia)*	*20*	*Bakhtiari (Iran)*
9	*Jie (Uganda)*	*21*	*Al Murrah (Saudi Arabia)*
10	*Turkana (Kenya)*		
11	*Rendille (Kenya)*		

Figure 10. *Distribution of the main pastoral and stock-rearing groups in Africa and the Near East (adapted from UNESCO Report. Tropical Grazing Land Ecosystems. 1979).*

Table 3. Main Types of Pastoral and Agropastoral use of Tropical Grazing Land Ecosystems, with the Corresponding Societies and Human Groups

Continents and Ecosystems	Hunting	Extensive Nomadic Pastoralism				Extensive ranching
		Mountain	Beduin type	Cattle pastoralists	Agropastoralists	
Africa and Madagascar						
Desert and subdesert zones	Bushmen	Arabo-Berber	Moor, Twareg, Tubu, Arab			
Sahelian steppes	Nemadi (Mauritania)		Somali, Arab	Nomadic Fulani	Moor, Twareg, Tubu, Arab	Beginning
Eastern African steppes	Dorobo		Somali, Arab	Nilo-Hamites, Nilotes, Galla	Nilo-Hamites, Nilotes, Galla and Bantu (Gogo)	Kenya, Tanzania
Southern African steppes				Hottentot	Many Bantu societies	South Africa, Rhodesia, etc.
Sudan savannas				Nomadic Fulani, Nilotes	Agropastoral Fulani, Nilotes, agropastoral Fulani (Futa-Jallon)	Beginning in eastern Africa, Sudan
Central African grazing lands	Caste hunters				Interlacustrine civilizations, Angola, Zaire	Angola, Zaire
Madagascar savannas				Malagasy pastoralists	Malagasy pastoralists	
Montane grasslands	Ethiopian hunters			Galla	Galla	
Tropical America						
Campos and *llanos*	Hunters					Brazil, Venezuela, Central America
Dry thornbush	Hunters (Chaco)					Brazil, Mexico, Chaco
Campos limpos						Brazil, Paraguay, Northern Argentina
Australia						
Arid zones						Australia
Formations in semiarid regions	Australians					
Woodlands						
Asia						
Arid zones	Caste hunters		Beduin			
Indian and Middle Eastern steppes		Afghanistan, Iran, Pakistan	Beduin		Indian pastoral castes	
Indian savannas					Indian pastoral castes	
Deccan savannas	Indian hunters, Vedda (Sri Lanka)				Indian pastoral castes	

Source: Adapted from UNESCO Report. Tropical Grazing Land Ecosystems, 1979.

Population figures for particular rangelands are often scanty or unreliable. Two important statements about the population of tropical rangelands can be made: 1) For hundreds of years tropical rangelands have directly supported and are today inhabited by a significantly larger indigenous pastoral population than similar rangelands elsewhere in the world, and 2) the majority of livestock in such areas are still raised primarily for subsistence, to support large and in many cases rapidly increasing human populations. Due to this large population, conventional rangeland practices that have evolved in areas of the world distinguished by the absence (or very small numbers) of indigenous pastoral peoples (such as Australia or the southwestern United States) may not be appropriate, or even feasible in many tropical rangelands. Innovations geared to the demographic conditions of the existing local production systems may be more promising.

In any case, hard data and trend indicators on the demographic characteristics of existing production systems are always necessary for assessing the potential for change as well as continuity. The types of such data are described in chapter 5.

Social Composition and Organization

Like all human communities, peoples of the rangelands are differentiated into distinct ethnic groups based on variations in language, customs, and cultural goals. These groups may be further differentiated by localized variations in social, political, and economic institutions that territorial segments (often called "tribes" or "subtribes") use to generate cooperation among their members and relate to their local environment.

Development planning must take into account such human diversity. Interventions that work successfully with one ethnic group or segment of it may fail in another due to differences in local social composition, organization, or goals. Further involvement in development and its benefits ought to be aimed at existing divisions of the population (such as tribes and subtribes) instead of at segments such as consumers or producers, men or women and children, etc. To view local communities as without internal divisions is to increase the probability that the innovations will have unwanted consequences, such as generating social divisiveness, that either impede their spread or outweigh their benefits.

Ethnic differences among peoples of the rangelands, and between these peoples and peoples from outside these systems, have special consequences for development planning. They imply different goals and customary ways of achieving them, and present problems for the two-way flow of information necessary to decision-making. In Africa, for example, many local rangeland communities consist of peoples who speak different languages. Except for Somalia, political leadership and national control of rangelands in Africa tend to be in the hands of ethnic groups belonging to language families different from those of local pastoralists. Pastoralists have tended to remain socially as well as geographically isolated from national or regional developments and relatively powerless to influence the direction of their change.

Indeed, pastoral areas remain underdeveloped in terms of educational, human health, and animal services; roads and communication facilities; and economic and other national infrastructures. This is at least partly because pastoralists in general have been poorly represented in, or have had inadequate access to, the decision-making processes guiding national or regional development policies. Their way of life has sometimes been viewed scornfully by others, who in the absence of information as to the rational basis for the differences, remain skeptical of the ability (sometimes expressed as the "willingness") of pastoralists to change. Thus, although substantial progress is being made in overcoming overt aspects of "tribalism" and other manifestations of ethnicity, a great deal of latent paternalism, mutual mistrust, and occasional conflict related to real or imaginary differences or perceptions of ethnic goals (i.e., stereotyping) still accompany many efforts to develop rangelands. Only when local peoples are equal partners in the planning and implementation process will meaningful compromises between local and national perspectives, goals, and needs be negotiated.

The cultural diversity typical of many tropical rangelands is especially evident in Africa. Africa has over 2,000 ethnically distinct peoples who speak over 1,800 mutually unintelligible languages. Precise social, political, and economic institutions vary enormously both within and among peoples, and their precise form must always be verified empirically in any particular area. For example, families commonly consist of compound polygamous units (i.e., a male head with two or more wives and children), which range in size and complexity. Some comprise "extended compound families" with married sons, their wives, and children. They are generally divided into distinct residential "household" units (sometimes dispersed) with **differential** management and ownership rights to "family" property. Though such families tend to be economically autonomous, they often share labor, property, and subsistence products with other families with whom they cooperate in the use and management of communal resources. In some instances such sharing takes the form of temporary voluntary associations. In others it is based on extended kinship rights and obligations vested in corporately organized lineages or clans, circumscribed by a variety of customary laws or practices.

It is not surprising, therefore, that many range management practices that have evolved from Western forms of social organization will require modification or change in order to meet the needs of existing forms of social cooperation among peoples of the tropical rangelands. The point to remember is that it is easier to adapt technology to local forms and varieties of social cooperation than vice versa. Technical interventions must, therefore, take account of these existing forms and assess the needs for and feasibility of modifications needed to ensure that the technology can work. Again, a **local** systems approach, involving full and equal participation of local people in the planning and implementation process, seems to be the best.

Land Tenure and Problems of Social Control

Few aspects of Third World range research and planning have been so conspicuously neglected as those relating to land tenure and the problems of social controls over range resources. As both the population and the conversion of resources into material things increase, the gratification of individual human wants becomes more important. Development must take this into account if environmental abuse is to be averted. In developing countries, as elsewhere, "rising expectations" have generated demands on an unprecedented scale. Newly independent, rapidly changing nations often do not have control over such trends as the increased demand for private ownership of land and greater individual access to or acceleration of resource use (Bennett, 1980).

In contrast to their many settled agricultural neighbors who developed politically centralized, hierarchical social systems based on chiefdoms, kingdoms, or traditional trading empires, most pastoral societies -- especially in Africa -- remain politically decentralized. They are highly resistant to political control, which restricts their ability to move their families or livestock regularly in response to rapidly fluctuating conditions. The belief in equality among families, communal ownership and management of rangeland resources, and significant institutionalized sharing of products from subsistence-livestock systems have always been hallmarks of traditional pastoral systems. Differences in "wealth" (measured mainly in numbers of children and in relations, and only secondarily in terms of livestock holdings) contribute to differences in social standing between individual families. Differences in wealth, however, seldom afford the basis for private rights or privileges to land or resource use over less wealthy families. Rather, individual goal attainment among most pastoralists is circumscribed by well-developed customary practices related to group consensus, austerity ethics, and the need for autonomous families to cooperate in the face of harsh environmental circumstances. Thus, equity remains a characteristic concern and vital issue among pastoralists, who tend to regard their scarce resources (land, water, and forage) as better managed for the general good when under public control.

Researchers and planners must be sensitive to these local issues and take into consideration the role that they play in controlling individual demands that often lead to environmental abuse. Measures of the carrying capacity must therefore not be restricted to number of livestock alone, but must also take account of the numbers of people currently being supported under traditional management practices and how this may be related to social organization or social control. Fixed, rest/rotational grazing schemes that depend for their success on private land-tenure systems, fencing, the exclusion of wildlife, etc., are unlikely to prove socially or economically sound for much of the tropical rangelands. Rather, new technologies incorporating local control systems are needed. It should not be forgotten that Western technology has its own history of cultural and environmental factors that influenced its development. Indeed, much of our technology tends to favor the well-to-do farmer or rancher, and suits our highly individualistic needs.

Diet and Household Economy

Among the many factors relevant to assessing the nature of particular rangeland systems and their scope for change is that of the subsistence preferences and practices of its human population. Many pastoral peoples abhor the eating of fish, fowl, and various wild animal or plant foods. They vary enormously in either their dependence upon, or preference for, agricultural products, even when readily available as substitutes for pastoral foods. Like people elsewhere, pastoralists tend to use food as a symbol of their cultural identity and unity, as well as a strategy for survival. The pastoral Maasai of Kenya and Tanzania, for instance, have a well-known preference for attempting to live mainly on fresh cow milk, and this is reflected in the high percentage of adult milk cows (often 72%) in their family herds. Keeping high numbers of breeding animals is a survival strategy in the face of dry seasons. It also permits the Maasai to rebuild their herds quickly and to continue to feed the relatively high density of people that such a strategy supports. Likewise, although Maasai men claim to loathe drinking goat milk, such disdain actually has the effect of providing their women, children, and elderly members with an important food supplement during long dry seasons.

Hence, although dietary practices are changing, the role of livestock in meeting local pastoralists' subsistence needs and preferences is a crucial aspect of intervention planning, and should be empirically verified in all cases. The degree of household, family, or local dependency on livestock for subsistence varies seasonally as well as socially. It also fluctuates relative to other needs, such as cash income to purchase basic commodities or to meet social obligations and debts (e.g., marriage or education). Indeed, particular pastoral production systems differ greatly, both between and within themselves in: 1) the degree or mix of pastoral enterprises pursued, including both subsistence and market production; 2) the ease and terms of trade for exchange of livestock for other goods, often influenced by both national pricing policies and markets as well as illicit, black-market sales; and 3) alternative sources of subsistence and income, including labor migration.

Data-Collection Strategies

The collection of data relating to socioeconomic dimensions of project planning and research should take several forms and be carried out in distinct phases. The specific types of data collected for analysis will depend upon the objective being pursued as well as the constraints that may be inherent in the project setting. Most essential is genuine interdisciplinary collaboration between social and natural scientists as opposed to the fragmented multidisciplinary efforts that characterize so much current development planning and implementation. Among the team members should be persons trained and experienced in working at the interface between social science and natural science, such as development anthropologists or human ecologists. People with experience working with non-Western peoples should also be included. Data collection for applied or adaptive research should have explicit objectives related to the solution of practical problems.

Phase I should involve collaborative quick-and-dirty field surveys designed to identify and roughly quantify specific rangeland problems that -- in terms such as "severity of problem," "area affected," "human/livestock densities," etc. -- are likely to have the greatest benefit for local people, if solved. The aim should be to construct preliminary profiles of local production systems, their resource base, and environmental conditions. Special emphasis should be given to collating **existing** sources of knowledge and experience of both local problems and previous development efforts, and their failures and successes. Attention should be given to collecting baseline data, to estimating trends whenever possible, and to identifying other information needed for the solution of particular problems. These surveys may also serve to provide the kinds of information needed about the human resources to facilitate project planning and development as described in chapter 6.

Phase II should aim at establishing preliminary priorities for interventions that reflect the relative importance of these constraints or needs for local as well as national development goals. Being both a research and evaluation process, it should involve interactive dialogue between researchers, planners, and local producers. Of special importance are data that clarify to whom and to how many people the problems or constraints are considered to be important, and why; and who would be the users and how much benefit they would receive if the need is met. In short, an explicit social hypothesis should be advanced as to how and why particular interventions are likely to prove successful, so that both the theory and the intervention can be tested.

Phase III would consist of the identification, testing, and evaluation of prototype interventions in the field under user conditions, to determine if they are relevant and within the existing capacity of small-scale producers to adopt and implement. Here data on costs to users in time, labor, and monies needed to solve the problem, probable magnitude of benefits, and local problems of control and implementation should be sought, to determine whether the expected results are valid or if the prototype intervention must be modified.

Only when all three phases have been successfully concluded is it reasonable to assume that the intervention is potentially valid and adaptable over a still wider diversity of conditions, and thus a serious candidate for demonstration or implementation by extension services.

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A state-of-knowledge report that presents a comprehensive review of rangeland ecosystems and man's patterns of use. Case studies from Africa, America, and Asia are presented.

Chapter 3

Animals

What and how much animals eat and their response in terms of production varies with the species of domestic and wild animals as well as with the quality and quantity of vegetation.

Cattle, goats, sheep, camels, donkeys, and various wildlife species differ significantly in their preferred diet and in their capacity to satisfy their requirements under varying feed and water scarcities. In addition to being part of the human food system, wildlife also contributes cultural and aesthetic values. Domestic and wild animals may also react in quite different ways to high temperatures, humidity, and disease. This chapter discusses these differences and how to use them.

Emphasis is placed on key animal-management considerations in relation to particular problems or goals, and to the conservation of renewable natural resources.

Primary Considerations

Range animal productivity largely depends on the kind, quality, and spatial and temporal distribution of feed, and those factors that may influence the ability of the animals present to use the feed effectively. In other words, the nutritional environment of the animals is dependent on both the feed and the animal.

Under certain conditions, the nutritional environment may be substantially modified through direct interventions such as hay-making, fertilization, supplementary feeding, etc. In most range situations of developing countries these interventions are not possible or practicable. Therefore, a primary aim in range management is effective use of existing range forage. A critical component for achieving this objective is the use of animals that are capable of eating and digesting the range vegetation available.

What animals eat is influenced by their evolutionary history, by the vegetation on which they depend, conditioning, selective pressures to which they have been subjected, and current conditions and management. Some of the ways in which management may favor the performance of range animals is illustrated in chapter 7. In this chapter, we will explore in some detail the origins of and differences among range animals, including responses to disease, and how these differences may be taken into account in order to secure better range utilization and productivity. Domestic animals -- cattle, sheep, goats, camels, and to a lesser extent donkeys -- will be dealt with in the first part of the chapter; this will be followed by a section on wildlife. Primary consideration is given to Africa, but many of the principles will be relevant to other areas with similar environmental conditions.

Cattle, sheep, goats, and camels had their origins in somewhat different environments. After domestication, each species was moved with migrating humans into a great number of still more different environments, and were used for a variety of purposes. Each therefore has certain qualities that characterize it as a species. Additionally, within each species there are substantial variations, largely unquantified, in degree of adaptation to particular nutritional and abiotic environments and for particular uses and even production systems. Game animals also show large variations in adaptation and other characteristics. Management of either domestic or game animals is largely a means for further harmonizing the relationships between animals, plants, and abiotic environments in order to achieve specific objectives. The management input requirements increase as the degree of adaptation of the animals to the environment decreases.

Characteristics of the vegetation that have a major influence on its suitability for different types of animals and management requirements include the following: composition or the relative proportion of grasses, forbs, and woody species; acceptability or palatability of each species; nutritive value of the various plants eaten; vertical and horizontal distribution of forages that may influence availability to different types of animals; and seasonal variations in quantity and quality of feed. Some illustrations of these characteristics were given in chapter 1.

Abiotic characteristics that are particularly important to consider, especially for domestic livestock, are mainly those that may limit or facilitate feed supply and influence the ability of animals to use the available forages and to reproduce. They include the following: rainfall distribution, frequency and duration of droughts, duration of maximum and minimum temperatures, humidity in relation to temperature; daylength (mainly important for importations of sheep), and water availability seasonally and spatially.

Drinking water influences to a marked degree the efficiency with which the vegetation may be used and the relative values of different animals. Where herding of domestic flocks is practiced, as in Africa, the influence of moderate topography on grazing distribution may be negligible. Diseases and insects often affect different animal species to different degrees.

While the biotic and abiotic components of the ecosystem will largely dictate what kind of animals and production systems would be most suitable, adjustments to meet human needs are often required. Furthermore, although each range ecosystem can be defined by certain norms, the biotic and many of the abiotic components of these ecosystems are in constant flux. Therefore, no fixed relationship among ecosystem components is possible. The only stability is a kind of dynamic equilibrium. This fact has long been recognized by range managers and ecologists in general. Nevertheless, there is a persistent tendency to concoct management systems that impose rigid rules, rather than providing the needed flexibility. The task of range managers then is to define the ecosystem components that are critical for effective management and to indicate how these components may be manipulated in ways that are economically and socially feasible.

Domestic Livestock

Origin and Distribution of Domestic Livestock

Probably the most important characteristics of the domestic livestock resource is its immense genetic and phenotypic diversity especially in Africa. This diversity is particularly important to the development process because it permits choices.

The diversity of animals in terms of environmental and nutritional adaptations has been only partially determined experimentally. However, the existence of immense genetic diversity is evident from the studies that have been made and synthesized in two remarkable volumes by H. Epstein, "The Origin of the Domestic Animals of Africa," as revised with I. L. Mason (1971). Many publications illustrate the range of environments in which various species and breeds of livestock are adapted.

The number of domestic animals in Africa according to the 1979 FAO Production Yearbook was approximately: 170,110,000 cattle, 171,846,000 sheep, 144,684,000 goats, 11,983,000 camels, and 11,734,000 donkeys. All these numbers increased during the preceding 10 years, but average carcass weights changed hardly at all. Kilograms of meat produced per animal in 1979 were as follows: cattle 16.5, sheep 3.8, and goats 3.5. This is an extremely small average yield -- even allowing for the fact that most of the cows are milked, and that a substantial number of animals slaughtered may not have been tabulated. Yield per unit area, however, may be somewhat more favorable. For example, yield of protein per hectare in the Sahel compares favorably with that of areas of comparable rainfall in the United States and Australia. The history of livestock populations in Africa is long and only partly understood. Some points that seem particularly important are recounted below.

Cattle, sheep, goats, and dromedary camels were first domesticated in the Mesopotamian region or elsewhere in the Near East. Donkeys were probably first domesticated in North Africa, where two wild species still occur. Sheep, goats, and cattle were all domesticated between 9000 B.C. and 5000 B.C., in that order. Dromedary camels may have been domesticated around 4000 B.C. in Arabia and donkeys some 500 years later, probably in Egypt.

Before domestication, the wild species of cattle, sheep, and goats covered an enormous range of environments and were additionally exposed to changes associated with glacial and interglacial periods. Interbreeding of different races also probably occurred. Domestic animals therefore started with a great deal of genetic diversity, which was subsequently further enriched by crosses with different geographical races of wild relatives. The wild dromedary camel and the donkey, on the other hand, apparently lived within a narrower range of environments. This may, in part, account for limitations on their current environmental adaptation.

Domesticated animals entered Africa for the most part through the Isthmus of Suez into Egypt between 5000 B.C. and 3000 B.C. Camels apparently entered somewhat later. They were known to Egypt in 2500 B.C., but were not in general use until Graeco-Roman times. Archaeological finds reveal a number of livestock-keeping sites scattered within a crescent ranging from West Africa through the Sudan into East Africa as early as 2000 B.C.

Three principal breeds of cattle were introduced: the humpless longhorn *(Bos taurus primigenius)*, humpless shorthorn *(B. taurus brachyceros)*, and humped zebu *(Bos indicus)*, in that order. The largest entry of zebu cattle probably occurred after the Arab invasion of Africa in 669 A.D.

The humpless longhorns constituted the first wave of cattle in Africa and came to be more or less generalized in North Africa and East Africa, and part of West Africa. One of the longhorn breeds, the N'Dama, still exists mainly in Gambia, Sierra Leone, Liberia, and Western Mali. It is a good beef animal but is mainly known for its high resistance to trypanosomiasis and tickborne diseases. Another surviving longhorn is the Kuri, famous for its thick horns and swimming ability. It is found in Nigeria around Lake Chad.

The humpless longhorn cattle were largely replaced by the humpless shorthorn cattle, beginning as early as 3000 B.C. in Mesopotamia. These shorthorn cattle now occur in Africa north of the Sahara in Egypt, along the coast from Gambia to Cameroon and in Zaire. Even today the shorthorn type is still the most common in Israel, Syria, Lebanon, and Jordan. The best known is probably the Damascus (shami) milking breed. Humpless Spanish cattle introduced by Columbus into Hispanola in 1494 evolved into highly adapted cattle and were gradually absorbed by introductions of zebu and other breeds except for a few scattered herds mostly in the Dominican Republic, Venezuela, Colombia, and Central America.

Zebu cattle are thought to have evolved some 4,000 years ago near the present border of Pakistan and Iran. Although entering Africa relatively late, their excellent adaptation and variability has permitted them to spread over much of Africa and to generate numerous types. Especially in East Africa, the zebu absorbed or superseded the longhorns and shorthorns. Crosses of zebu and humpless cattle resulted in widely distributed African cattle known as Sanga breeds. Zebu types have spread over much of tropical America and other areas with warm climates.

All sheep may, according to Epstein, have evolved from the wild mouflon type. As with other domestic animals, the immense variation that may be observed is the result of high initial variation, and further variation accumulated over thousands of years of environmental and directive selection.

African sheep have been classified as hairy thin-tailed, wooled thin-tailed, fat-tailed, and fat-rumped. The hairy thin-tailed sheep consist of two distinct types: the savanna type found mainly in northern Sudan, the northern part of West Africa, Gambia, Angola, and Damaral; and the tropical forest type found in the humid regions of Sudan, the Nigerian coast, and parts of Angola and Zaire. The wooled thin-tailed sheep consist principally of fine-wooled and coarse-wooled maghrib sheep in Algeria, Morocco, and Tunisia. Some of this type are also found in the central delta of the Niger and in Sudan.

Fat-tailed sheep now occur mostly from Algeria eastward into Somalia and southward to East Africa, Rwanda-Burundi, Malawi, Zambia and Zimbabwe, and South Africa. Those in North Africa are similar to those in the Near East, of which the Awassi breed is the best known. Of the fat-rumped sheep, the black-headed Somali is outstanding. Fat-rumped sheep also occur in parts of Ethiopia, the north of Kenya into the Toposa area of Sudan, in the Central Province of Tanzania, and in South Africa. They are especially adapted to dry areas.

Fat-tailed and fat-rumped sheep are thought to be good examples of animal selection designed to meet human needs. In this case, the need was for fat in very dry areas where oils and fats were otherwise not easily available. The fact that the rump or fat tail also serves as a place for reserve energy storage is probably only coincident with the human objectives.

The goat is the most ubiquitous of domesticated animals in Africa. It is well distributed even in the humid forest. Most goats, and the largest range of types, are found in the savanna regions. Geographically, they are most abundant in the semiarid parts of the countries immediately to the south of the Sahara from Senegal to Somalia. As with sheep and cattle, their size generally decreases toward the equatorial region. Nubian types, well known for their milk qualities, occur in several countries and are especially numerous in Sudan. Due to their high rate of reproduction and rapid growth, goats have been reported more productive in relation to their total biomass than other species.

In Africa, the donkey is far more important than the horse because of its wide utility as a beast of burden to the pastoralists. Donkeys are most common in the northern countries of Africa, and to the south along the east coast. In the Sahel, they are restricted mostly to where Moslem people live. As in other species, there is much variation in size as a consequence of both breeding and feeding.

The dromedary camel in Africa is found in most of the arid regions. Its southern extension is restricted by humidity and the tsetse fly. Various breeds occur, some particularly suited for packing heavy loads, others for riding. Use varies -- for example, Somalia has more camels than any other country but they are not ridden. No breeding is done to produce a meat animal for slaughter, nor has attention been given to improving milk production. The estimated relative abundance of the domestic animals licensed on the principal rangeland systems is shown in table 4.

The main conclusions to be drawn from the preceding summary are: 1) Cattle, sheep, goats, camels, and donkeys in Africa have gone through a long and intensive screening to fit them to the environments they are in and to the purposes they fill; 2) improving that fit will require scientific and technical knowledge as well as the hard-won knowledge and experience of the pastoralists; and 3) the manifest genetic diversity should be adequate to meet most foreseeable future selections and breeding needs and as such deserves much more study and consideration than it has received. Similar conclusions apply to other tropical areas.

Adaptation to the Abiotic Environment

In the tropics and subtropics, cold is not often a significant constraint to animal production, except for animals such as lambs and kids born during a rainy period. Special care and protection during these times could reduce mortalities substantially.

Heat, especially when associated with high humidity, is a major constraint to the production of European types of animals in the tropics. Milk yield of European cows is not affected by temperatures between 0°C

Table 4. Estimated Relative Abundance of Domestic Livestock on Principle Rangeland Systems in Africa

Systems	Humped Cattle	Humpless Cattle	Hairy Thin-tailed Sheep	Wooled Thin-tailed Sheep	Fat-tailed Sheep	Fat-rumped Sheep	Goats	Camels	Donkey
Savannas with grasses 	Very common	Not common to scarce	Very common	Scarce to none	Common	Common	Very common	Not common to scarce	Common
Deciduous forests with high grasses 	Common	Scarce to none	Common	Scarce to none	Not common to scarce	Scarce to none	Not common to scarce	Scarce to none	Not common to scarce
Desert shrub and grasslands 	Not common to scarce	Not common to scarce	Not common to scarce	Common	Very common	Very common	Very common	Very common	Very common

Systems	Humped Cattle	Humpless Cattle	Hairy Thin-tailed Sheep	Wooled Thin-tailed Sheep	Fat-tailed Sheep	Fat-rumped Sheep	Goats	Camels	Donkey
Tropical rain forests 	Not common to scarce	Scarce to none	Not common to scarce	Scarce to none	Scarce to none	Scarce to none	Not common to scarce	Scarce to none	Not common to scarce
Winter rainfall vegetation 	Scarce to none	Very common	Scarce to none	Very common	Not common to scarce	Not common to scarce	Not common to scarce	Not common to scarce	Not common to scarce
Montane forests 	Not common to scarce	Common	Scarce to none	Common	Scarce to none	Scarce to none	Not common to scarce	Scarce to none	Not common to scarce

and 21°C; above 27°C, it generally declines rapidly. In contrast, zebu (Brahman) cattle maintain yields in temperatures as high as 32°C to 35°C. These limits, while highly indicative, should not be accepted as final until more field data are available. Certainly some European cattle such as the Spanish-derived "criollo" of tropical America have adapted very well, which may be partially due to slower growth and less milk production. Adaptation of these cattle through selection was undoubtedly facilitated by high initial variation, which is not a characteristic of most modern European breeds.

Growth of young European cattle is depressed when temperatures remain above 24°C. Weight gains may cease completely at 29°C to 32°C. Heat stress will reduce prenatal growth and also shorten the duration and intensity of estrus, thus sharply reducing reproduction in unadapted cattle. The effect of temperature is manifested through lowered food intake and physiological changes such as reduction in the level of thyroxine. Over a long period of time these constraints may be partially overcome by strenuous selection, assuming enough variability exists initially, but it is hardly a practice to be recommended. However, selection of highest producing animals is a valuable short-term tool in improving local livestock.

Adapted animals like the zebu have more effective cooling mechanisms than European types, particularly through more sweat production at high temperatures and a somewhat larger surface area per unit of weight. Additionally, hairs are short and close to the body, thus releasing heat readily and reflecting more incoming radiation. In hot climates, the zebu consumes a higher rate of dry matter per unit of body weight, and has a higher digestibility coefficient and higher absorption from intestinal metabolites than do European cattle. The rate of metabolism of the zebu at high temperatures is also lower than in European types.

One of the general evolutionary effects of heat stress and associated nutritional stress is a decrease in body size. A benefit of this is that less food is required for maintenance, and heat dissipation is increased by the higher ratio of body surface to volume. However, small size also implies a higher rate of metabolism, which counteracts to some degree the advantages. The slower rate of metabolism characteristic of the zebu may help to explain why it appears to be able to grow better in the tropics than other cattle. The incompatibility of size and heat tolerance is one of the reasons why most introductions of genetically homogeneous, temperate animals into the tropics have not been successful.

Symptoms of heat stress include reduced milk production, slower growth, and fewer pregnancies. During lactation, heat production may be doubled in high-producing milk cows, a further reason why milking Holsteins usually appear miserable in the tropics.

Rumen microorganisms account for as much as 10% of the basic heat produced by an animal. Exercise also generates excess heat. For example, heat production is more than 10% greater in cattle and sheep that are standing than in those lying down. Animals grazing or being driven are obviously generating still more heat. From this it may be deduced that the easy-going way that traditional African pastoralists handle livestock has much to recommend it.

Heat loss is through radiation, convection, conduction, and evaporation of water. Only evaporation is sure to result in loss of heat from the body, since the other heat-transfer mechanisms may work in either direction. In cattle, the amount of heat absorbed from the sun may greatly exceed that produced by the animal's metabolism. This is one of the reasons why allowing the animals to graze early in the morning and late in the evening is important. It also explains why animals that are not well adapted avoid grazing during the heat of the day.

Rate of heat loss through evaporation of water from the skin and the other respiratory surfaces is of major importance for most animals. This rate depends on the animal and the humidity, or more exactly on the difference between the vapor pressure of the evaporation surface and the adjacent air. Air movement reduces the humidity next to the evaporating surface. For this reason persistent breezes where air temperature does not exceed body temperature, as in the Caribbean area, will ameliorate the effects of high temperatures. Cool nights may compensate for high daytime temperatures. High daytime evaporation and low night temperatures, as in arid climates, make for easier adaptation than do humid climates with similar or even lower daytime temperatures.

Heat loss through evaporation is also accomplished by panting, which is especially important in sheep and goats. Wool protects sheep against heat flow from the environment. In fact, as observed by Schmidt-Nielsen (1964), sheep are the most drought- and heat-resistent of any medium to large animal, aside from the camel and some wild antelopes.

Some degree of acclimatization of breeds not adapted to heat does take place with continuous exposure. However, this is accompanied by decreased food intake, and decreased production and reproduction. As previously stated, adaptation depends on the opportunity for selection, i.e., the genetic variability.

Water requirements are important to adaptation in hot and dry environments. Most critical is the length of time the animal can go without drinking, without its performance being affected. Where watering places are widely separated, this characteristic is basic to achieving uniform utilization of the vegetation.

Water intake varies with temperature, humidity, feed supply, stage of growth, pregnancy, lactation, and activity. For example, in sheep the normal daily water consumption is 3 liters to 4 liters, but at high temperatures it may rise as high as 10 liters. Water consumption of lactating European dairy cows at temperatures below 27°C may be as high as 60 liters to 80 liters, compared to 30 liters for zebu cattle. Nonlactating European cows may consume only 20 liters to 30 liters, compared to 15 liters to 20 liters for zebus. Consumption increases rapidly as the temperature rises and may exceed that of camels by about four times.

Goats use less water than sheep and only about one-half as much as cattle, relative to their size. Camels have by far the lowest requirements.

The camel's economic use of water is to a considerable extent due to the fact that, unlike most animals, it can tolerate daily changes in body temperature of 5°C or 6°C without ill effects. The stored heat in a 500-kg camel may amount to 2500 Kcal. Instead of this heat being lost by sweating (requiring about 5 liters of water), it is simply lost by cooling during the desert night. Further, when camels are deprived of water, their water loss through sweating is sharply reduced. They can lose water equal to more than 15% of their body weight without apparent reduction in appetite, and over 25% without apparent ill effect. In contrast, European cattle typically lose their appetite before having lost 12% of their weight to dehydration; with a loss of 12% to 14%, large and possibly fatal increases in body temperatures may occur. The camel's hair helps by providing some insulation. How long camels can go without water varies with temperature and the amount of water contained in the vegetation. They have been known to travel 21 days without water during winter in Saudi Arabia, but 5 to 7 days would probably be closer to normal. Significant differences may exist among camel breeds.

The donkey, like the camel and sheep, can tolerate dehydration of 30% of its body weight. The donkey is not, however, a particularly efficient user of water, needing two to four times as much as the camel in relation to size. Loss of appetite occurs when water loss approaches 20%. On balance, the donkey also is remarkably well adapted to a dry, hot climate. It should also be noted that certain game species such as the desert gazelle, desert oryx, ibex, and others have the capacity to survive with very infrequent drinking, due to use of metabolic water and low loss of water.

Adaptation to the Nutritional Environment

The abiotic and biotic environment determines the type of vegetation present, its period of growth, and its quality and quantity. The abiotic environment also, as we have seen, strongly influences the capacity of different animals to use the vegetation effectively. Consequently, the quality or adequacy of the nutritional environment of rangelands depends on the interaction between the animals and the forage plants that are present. Seeking a desirable relationship ought to be the first function of management. A few examples may illustrate the process.

It is well known that animal species are able to use plants in significantly different ways. (Important differences undoubtedly also exist within animal species, but these have as yet been studied very little.) For example, camels can eat more woody shrubs than any other of the domestic species, roam farther from water to eat, and reach parts of trees that would not be accessible even to goats. Goats also make effective use of shrubs and are especially adept at selecting leaves and other high-quality parts of the plants. They cannot move nearly as far from water as the camel. Cattle and sheep prefer grass. Sheep, however, will eat more tender shrubby material and have a strong preference for forbs. They prefer short to tall grass and can graze to the base of the plants at soil level. These many differences in eating habits require that projects deal with several types of vegetation rather than with a single species.

We do not presently have enough knowledge to put together a precise combination of animals to fit particular range-vegetation species. However, with information on plant composition and knowledge of food preferences of the different species, approximations of animal requirements can be made, subject to adjustment according to experience.

Because of their food preferences animals may also be used to some extent to control the composition of the vegetation. For example, goats may help to control brush. Cattle may reduce the dominance of tall grasses, allowing a greater diversity in vegetation that may favor other animals such as sheep and wildebeests. For example, cattle are grazed in southern Brazil, Uruguay, and adjacent parts of Argentina to favor sheep.

Aside from the factor of relative preference or selection of plants by animal species, consideration must be given to how the physical environment affects the appetite of the animals. This may be particularly important in the humid tropics due to the inhibiting effect of climate on appetite and the low quality of the forage. Grasses in the unfertilized humid tropics are generally 10% (or more) less digestible than grasses in temperate areas. Intake of tropical grasses is also lower. As a result, animal performance in the lowland tropics is practically always poorer than on most temperate grazing lands. This is perhaps the main reason why adaptation is so critical in tropical animal species and why introduction of temperate European breeds has usually failed.

Figure 11. *A goat nibbles the leaves from among the thorns more efficiently than other domestic animals, except perhaps the camel.*

Because they have been there so long, it can be assumed that the breeds in Africa are well adapted to the area in which they are found, whether they be *Bos taurus, B. indicus*, mixtures of the two species, or the various breeds of sheep, goats, and donkeys. Undoubtedly important differences exist that should be understood. What is needed are critical studies of this wealth of genetic material so that it can be used for a more rational development of the animal resources in Africa and elsewhere.

Diseases

Poorly fed animals are more susceptible to disease, and are less likely to survive than those that are well fed. Disease worsens malnutrition by reducing appetite. Usually malnutrition impairs the functioning of the host's immune system since normal antibody response may be inhibited if protein deficiency is sufficiently severe. The effect can be disastrous in the case of animals infected with internal parasites that compete with the host for the nutrients in ingested food. Such competition is most critical in tropical countries and in young animals because the nutritive quality of the forage is already marginal for meeting the maintenance and production-function needs of animals. However, it is well known that only in rare cases will infection cause death of a natural host, as opposed to numerous losses when exotic hosts become infected. Therefore, to be parasitized is not necessarily a pathological condition, but rather a normal state of affairs, particularly in the tropics. Heavy parasite burdens have been discovered in apparently healthy game animals.

Few domestic animals in tropical Africa and in other tropical countries are fed at a level that permits them to approximate their production potentials. Sheep and goats, however, are better able to survive extreme deficiencies of forage than are cattle. This may be due to their superior ability to select the best parts of the available vegetation and to graze more closely than cattle, as well as to their lower requirement per animal. Camels also have a great capacity for survival due to their ability to use a wide range of forage plants, including the coarser parts of shrub and tree species, and their ability to graze over a very large area without water.

In general, the effort and money spent on disease control have to bear a close relationship to the value of the animals being protected. That in turn is a function of quality and price, largely dependent on feeding and favorable markets. Development programs must therefore give first priority to improving feeding and to fostering management as the most practical means available for reducing the impact of disease, and so bringing nearer the day when adequate veterinary services can be fully justified. Nevertheless, general animal-health assistance training is a valuable tool in educational programs for pastoralists, and alone may gain confidence for further range practices. The approach of linking animal health with production deserves major emphasis along with continued efforts on control of epidemic diseases. Both offer good possibilities for increased cost-effective production efficiency.

Game animals may reduce the amount of feed available to domestic animals, especially when the domestic stock contains several species that cover a broad range of dietary preferences. Furthermore, game animals are alternate hosts for a number of diseases such as trypanosomiasis, heartwater, other tickborne diseases, and rinderpest. This further complicates disease control and has led some to believe that multiple use of rangelands by game and domestic stock should be avoided. This, however, is not an issue likely to be settled, except on a case-by-case basis.

In the paragraphs that follow only brief mention will be made of some of the diseases affecting domestic livestock in Africa, and then only to suggest the directions that are appropriate for development.

No doubt a major role of animal-health specialists is in the control of devastating epidemic diseases such as rinderpest and East Coast fever. Due to the international implications of these types of diseases, cooperation among affected countries should be further strengthened. Strong support of donor agencies is also important for avoiding catastrophes such as have occurred in the past. Although rinderpest can affect other stock, it mainly attacks cattle. This is another compelling reason for maintaining species diversity to reduce risks.

Attempting control of foot-and-mouth disease, which is endemic to Africa, may not be justified at the present stage of development.

Although losses may be significant, especially in reduced growth rate and in lowered milk production, the costs are likely to be too high to justify programs for control. However, due to many international markets being closed to meat exported from places with foot-and-mouth disease, justification for control might well increase. For example, immunization programs carried out in Argentina, which depends very much on exports, seem to be well justified.

Control of the tsetse fly, or an effective, cheap method for immunizing against or otherwise reducing the effect of the trypanosomic protozoans, would make possible effective livestock production on an additional 10 million km^2 in Africa. Maintaining a modified environment unfavorable to the tsetse fly, control of the fly through chemical or biological techniques, and immunization of animals, are under continuous evaluation. All present tremendous obstacles, and for the time being no generally applicable, practical solution is in sight. Selection for resistance may prove to be the best way to proceed. This would imply more concerted work with the N'Dama and other cattle breeds as well as goat breeds, which are known to possess varying degrees of resistance, and more effective use of wildlife.

At the present time animals from noninfected areas cannot be moved into tsetse areas without risk of infection.

Other diseases occurring widely in semiarid tropical Africa are contagious bovine pleuropneumonia (CBPP) and contagious caprine pleuropneumonia (CCPP).

Anthrax, a bacterial disease, affects all domestic animals and man. Vaccines are available, but not widely used because of expense and lack of availability at the local level. Sheep pox and goat pox are quite common. Various tickborne diseases, such as red water, anaplasmosis, East Coast fever, and heartwater are common.

Tickborne diseases are controlled mainly through dipping, which needs to be carried out systematically. Cost, an increasing resistance of ticks to the dip, and effective control of dip quality and procedures, are major obstacles. In the long run, more resistant cattle are needed. Actually, in Africa one may anticipate considerable natural resistance in domestic animals because they have been exposed to that environment for many generations. In tropical America, the *Bos taurus* creole cattle have evolved a natural tick resistance similar to that of zebus. Knowledge of variation in tick resistance among and within breeds is needed. Induced resistance (development of the "carrier state") may be of particular importance for some diseases, such as anaplasmosis.

Pasture management aimed at reducing tick infestation, as through periodic rest and burning, may be important, as will better vaccines and therapeutic drugs.

Roundworms, tapeworms, and flukes are especially common in the humid tropics, and elsewhere during the rainy season. These parasites have two characteristics critical to the strategy to be used for their control: 1) They do not multiply in the animal host and 2) part of their life cycle must be spent outside the host. The main management objective should be to prevent animals from ingesting large loads of parasites. This can be done by avoiding regrazing of infected areas long enough to markedly reduce the parasite population. During the wet season, this may take 2 to 3 months, but much less time may be required during the dry season. Close grazing to admit maximum exposure of the eggs or larvae to the sun and drying will also be helpful during the wet season. But this practice should not be followed unless rest periods from grazing of 2 to 3 months can be provided, and then only for a very short time since inadequate nutrition upsets the equilibrium between the parasites and the animal.

Young animals are especially sensitive to parasities. Therefore they should be managed with special care to avoid high parasite loads and to maximize nutritional intake. For example, they should when possible be the lead group in any move to fresh grazing, as in rotational schemes. For all animals, better grazing management during the wet season could reduce the parasite burden while increasing feed intake.

Liver flukes are associated with areas where standing water is common. The most practical control is keeping stock away from those areas. If use of standing water is necessary, it is best to draw it into troughs so as to exclude the snails in which the flukes spend their intermediate larval stage.

Diseases caused by deficiencies of essential minerals are less probable in Africa than in many other places (such as the savanna areas of north-central Brazil, Colombia, and Venezuela). This is due to the wide-ranging movement of the animals, which gives them access to plants grown on different soils. Furthermore, African soils are not so severely mineral-deficient in such huge areas as are some parts of South America. Also, African animals probably have access to a greater variety of plants -- grass, shrubs, and trees -- than do animals in many other places. In short, deficiencies are most likely to be found in the livestock of settled farmers or pastoralists. A low total intake of nutrients accentuates the effect of existing deficiencies. Such deficiencies do not affect all domestic animals to the same degree, due to differences in dietary preferences.

Adjustment to Human Needs

A high proportion of the nutritional needs of traditional pastoralists is likely to be derived directly from their livestock. For Africans this is mainly milk, meat occasionally, and blood among some tribal groups. This means that it is very important that the milk supply should not be below minimum needs during the worst part of the year. The main obstacles are variations in forage supply due to the dry season, spatial variation in rainfall, and drought. Moving animals so that they have a relatively steady supply of feed has been a common means of adjusting to variations in rainfall and thereby assuring a more regular milk flow. The greatest risk in migratory systems is not being able to find fresh grazing to which the herd(s) can be moved. Other tactics are to ensure that adult females constitute the majority of the herd, that breeding is yearlong, and that the period of lactation of the individual animal is extended as much as possible. The latter may be done through delays in rebreeding after parturition. Camels and goats may also help to assure a continuous milk supply. Goats, for example, may in some places be the main source of milk. Additionally, goats play an especially important role in providing protein and income for the rural poor in Africa and other developing countries. This is another reason why goats should receive more attention. Goats and sheep, however, are generally more important for meat, and as a partial substitute in case of a milk shortage.

Extended drought is always catastrophic. For example, livestock losses in Mauritania during the 1969-1973 drought were estimated as more than 70% of the national herd. In Niger, some 63% of the cattle, 47% of the sheep, and 33% of the goats were reported lost. Camels were least affected. These estimates are based mainly on physical presence, which was reduced by migration to the south, increased slaughter, marketing, and sharply reduced rates of reproduction as well as by death. More precise data on what happens during droughts are badly needed.

Normally, during droughts migrations are extended beyond that of the ordinary year. However, this doesn't help if there is intense competition for the same grazing, as is usually the case during a drought. This competition, due to the general shortage of feed, is often aggravated by the rise in numbers of livestock during favorable years preceding droughts. Risks are lower in herds that include goats and camels, as shown by the data from Niger.

In fact, experience suggests that herds containing a mix of different species use the typical tropical mixture of plant species more effectively and also reduce the impact of droughts. The high proportion of adult females (many of them unbred) often found in these herds favors survival of a breeding nucleus, and results in a rapid buildup of numbers following the drought. Sheep and goats, particularly the latter, may be especially important in rebuilding stock numbers, due to their low cost and rapid reproduction and growth. This is no doubt helpful to the individual pastoralist, but it may slow or prevent range recuperation.

Some tribal groups have intricate relationships of reciprocal loans and other arrangements to reduce individual losses and to further the rebuilding of herds. Trends toward more dependence on markets and weakening of old arrangements are occurring in many places. To what extent the effects of the 1969-1973 drought may have been exacerbated by changes away from traditional interdependent systems is not known. It is certain, however, that the major influences increasing losses were the long duration of the drought and the relatively high numbers of animals at its beginning.

Understanding the traditional ways of reducing the impact of drought may be critically important when trying to reduce or avoid social disorganization during drought. Loss of animals to drought may be the only way currently available for maintaining a dynamic equilibrium between the range vegetation and the animal population. However, ways of reducing the loss of dying animals should be sought, especially to salvage animals for slaughter. While it would be impossible to refrigerate the carcasses, salting and drying, as done in parts of Brazil, or other techniques should be considered.

It is urgent to learn how to better forecast forage conditions so that the need for adjustments in animal numbers can be anticipated as early as possible. An international project similar to the one on locust detection and control with FAO would seem a good approach.

Moving animals to new grazing areas also helps to reduce disease. Maintaining ample space for each animal, as through moderate stocking, would probably reduce disease as well as help to provide more adequate nutrition.

Under present conditions the benefits of migratory movements are being seriously compromised by competition resulting from the extension of crop agriculture and population growth. Further, as the competition for grazing increases, so will grazing intensity, while forage intake per animal will decrease. This in turn will mean a reduction in milk yield, and the need to compensate by increasing animal numbers and modifying the proportion of different species. Given the limitations of the natural resources, animal numbers and productivity can be expected to level off in the not-too-distant future, leaving decreasing supplies of animal products per person.

As has been stated, a series of good years leads to rapid increases in animal numbers, and large losses during bad years. Nevertheless, circumstances vary considerably from place to place. Not every family is equally responsible for overgrazing -- some families have many more animals than do others. Reducing stocking in proportion to the surplus over subsistence requirements might be logical but certainly not easy without attractive alternative investments. It is possible also that the families with larger herds may play a stabilizing role in replacing lost stock, etc. The advantages or disadvantages of relative wealth in such egalitarian societies need to be understood better. Considering the importance of these issues to programs and projects designed to assist livestock producers, there is an astonishing lack of information. Range projects should, therefore, gather data on exactly how the range-production system works within the project area before intervening.

To illustrate the complexities, consider one common situation: Overstocking is found to be the main cause of low productivity in a particular area. Possible solutions might include: finding alternative employment for some of the people; changing the diet from milk to more grains so fewer animals would be needed; growing additional forage; integrating with farming areas; and changing the proportions of the animal species combinations, or grazing patterns. The alternative to be adopted depends on the specific situation, and cannot be generalized.

What can be done also depends much upon factors external to the pastoral environment such as adequacy of markets, demand, transportation facilities, etc. The choice of alternatives available will ultimately depend mainly on the rangeland people being affected. Range programs can help them understand the alternatives.

When transportation, markets, and adequate prices are available to pastoralists, and they can regularly purchase consumer goods, especially grain, they tend to enter the market economy and gradually reduce their dependence on milk. This trend also allows them to concentrate more on producing animals of higher quality, to reduce the number of adult female animals, and to sell more young animals. By selling animals and buying grains to substitute in part for milk, pastoralists could generally increase their families' energy intake.

With this type of transition, the nutritional requirements of the herd could be better coordinated with the variations in range feed supply through control of breeding, reduction of stock numbers through sale before the dry season, etc. Dependence on migration in order to cope with fluctuations in feed supply would be reduced, although movements would still be beneficial and, in the dryer regions, necessary. It would still be appropriate for the pastoralist to keep a number of animal species in order to meet various needs and to utilize effectively the vegetation types that are available, as well as the labor supply in his family, and to reduce the risk associated with the drier-than-normal years. The purely commercial private rancher specializing in beef production might be an exception in preferring to work with only one species.

The pressure of population plus the availability of grain varieties with a very short growing season will inevitably mean more farming in the dry range area and a continuing reduction in the area of the best grazing lands. More and more pastoralists will no doubt be involved in farming. Some peasant farmers have found it economically interesting to buy young cattle from pastoralists for fattening. This type of informal arrangement could prove successful and mutually beneficial with minimal risks to peasants and pastoralists. Stockmen with ranches of especially high potential have for some time made a business of buying stock for fattening. It should not be assumed, however, that fattening can only be done in a few places. The main requirement is having enough feed to permit satisfactory animal growth. More consideration should be given to the possibility for setting aside special areas for allowing young stock to reach market size more rapidly, where good sale prospects exist.

It would be ignoring the deep cultural roots and the successful history of the milk-based economy to think that an easy transition can be made to a money-based economy. Further, the economics based on widespread commercialization are at best complex and subject to failures, especially in poorly developed economies. An example of this occurred during the Maasai Development Project:

> When livestock owners judged their herds would be unlikely to survive the season, they came forward with large numbers for sale. At this point, the commercial system failed; it could neither absorb large numbers of animals for transport to distant slaughterhouses, nor could it pay a fair price for a few better quality animals purchased. In time of drought, the small shops in Maasailand had no feed to be purchased at any price -- making a mockery of our urging people to convert stock into money for use during times of hardship (Morris, 1981).

Another problem in many places is irregularity in the supply of animals either for fattening or for direct marketing. This discourages overinvestment, overprograming, and rigidity.

Animal Improvement

Animal improvement through breeding is generally aimed at increasing yields of meat, milk, or wool. This objective may be accomplished through such means as the introduction of superior genetic stock, upgrading, crossbreeding, systematic selection, and culling.

In any process of improvement, the first characteristic to be sought is adaptation to the prevailing biotic, abiotic, and human influences. If there is lack of adaptation to any of these, additional costs to compensate for the inadequacies are inevitable. Where there are deficiencies in all three, failure is virtually certain even with substantial investments to compensate for the deficiencies. Favorable responses of animals subjected to exceptional and frequently very costly management are too often considered as indicative of adaptation. This has led to many costly errors, and policies that had nothing to do with improving the national herds.

From this it follows that the first objective should be to make maximum use of adapted indigenous stock in any breeding program. Adaptation in the tropics usually has to include tolerance to heat, hunger, and stress from inadequate water, as well as response to various management levels. Resistance to common diseases, especially trypanosomiasis, is also an important characteristic. Adaptation to the vegetation available should be given more weight than it has received to date, and adaptation to stress needs to be better understood.

In the process of optimizing relationships between the animals, environment, and human needs, differences among and within species are of major importance. Breeding programs, especially those including introductions of exotic stock, have assumed an adequate or improving nutritional environment, as has been been the case in many parts of the western world. In most African and other developing countries, however, the nutritional environment has not been improving, but has actually been deteriorating in many places. Hunger stress for a substantial part of the year is common even when deterioration is not evident, and any improvement must take these conditions into account.

Therefore, animal improvement in practically all African pastoral herds will need to be done through culling and selection, as is currently done in some areas. Culling and selection are easily understood and can be widely applied. Even though the results may not be spectacular, they can be significant. Improvements in this approach should be kept simple and take into account current practices in each project area.

In conjunction with selection and culling, some improvement in feeding, as through better grazing management, will likely be necessary in order to allow potentials to be expressed. While breed improvements must be aimed at individual species, this should be done within the normal production context, including herds of mixed species.

Use of improved and adapted sires, preferably selected through progeny tests, would be the next logical step after a within-herd selection-and-culling program is in place. Crossbreeding and use of high-potential sires not well adapted to the normal environmental stresses require advanced management and much better nutrition than is generally available. The limits on breed improvement are eventually set by feeding and management as conditioned by the environment.

Wildlife Resources

Wildlife and People

Wildlife are important cultural, social, recreational, and economic resources in any country. Many species have great economic impact as game animals, as sources of meat in protein-deficient regions of the world, as objects of interest in commercial tourism, and often as enemies of and competitors with man and his agricultural pursuits.

As could be expected, throughout man's long history various relationships to wildlife have developed and become part of his traditions, religions, and social mores. Hunter/gatherer societies formed a strong kinship with and respect for wildlife and its environments because these resources meant life to them. Not surprisingly, they developed traditions and customs to protect animals on which they depended. Other societies have religious precepts and doctrines that prohibit harming or using any animal. In some places, this has resulted in damage to humans and to agriculture and industry. Some species of wildlife have been adopted by tribes or ethnic societies as totems that are treated as protectors of their societies; other animals are used as sources of food, clothing, and other products. Recreational uses of wildlife in sport hunting, game viewing, and nature study are practiced in some parts of the world, but some of these uses are completely rejected in other regions.

Some wildlife devastate crops or kill domestic livestock and poultry. Others compete for forage and transmit dangerous pathogens to domestic animals. Still others are dangerous to man, directly or indirectly, because they serve as reservoirs and vectors of diseases and parasites for which he is an intermediate or final host. A few are known to attack man in certain situations, and the bites of some may be fatal.

In short, wildlife is a vital part of man's world and environment, and must be dealt with by each society and considered in its institutions and economic life. In order to know how wildlife may best be managed to achieve given objectives it is necessary to assess the animal populations and their habitats.

Management and Conservation

In resource management and conservation, wildlife includes all non-domesticated members of the vertebrate classes of *Pisces* (fishes), *Amphibia* (frogs, toads, salamanders, and their allies), *Reptilia* (lizards, crocodiles, snakes, turtles, and their allies), *Aves* (birds), and *Mammalia* (mammals).

Every hectare of land harbors some form of wildlife. Farmlands, grasslands, woodlands and forests, shrublands and savannas, marshes and swamps, and estuaries are the ecological contexts where wildlife attains its greatest economic and esthetic values. It is also in these environments that man finds the greatest need for management of desirable species and control of undesirable ones. Even large cities and villages with large numbers of people have habitats, albeit artificial ones, that harbor wildlife. Here also wildlife is used, but more often it is a nuisance that must be managed (controlled) if risk to people is to be avoided.

Like agricultural crops and domestic livestock, wildlife is a product of the land and must be planned and provided for in development programs. Natural laws control its importance in each environment, but the key influence is man. He makes most of the decisions about how the land is used and the resources allocated to achieve useful products from his agricultural systems.

Figure 12. *A gemsbok in the Kalahari desert of southern Africa.*

Quite different measures may be required to conserve and manage wildlife, depending on the situation. Sometimes complete protection may be needed in order to restore a species to a level where it can be used or to prevent extinction of a threatened species. By and large, however, wildlife management is practiced for sustained yields for the public good as well as for the preservation of wildlife.

Conservation applies to genetic material as well as to species per se, implying a preservation of genetic variability, which if lost is lost forever. Additionally, protection of threatened species and valuable ecosystems such as rangelands can be defended on ethical, social, religious, and economic grounds. Objectives in management must be to avoid waste and depletion of wildlife and to further its use as a renewable natural resource in production systems. Careful exploration and study to determine the status, requirements, and habitat of wildlife are preconditions for determining productive uses and management. This emphasizes the importance of resource assessment, which is discussed in chapter 5.

Ordinarily, conservation and management of wildlife is in unhusbanded and free-ranging populations. However, aquaculture (farming of water for fish, shellfish, algae, etc.) and game ranching (farming or production of wildlife in husbanded populations) are beginning to become important in many countries. The potential of aquaculture for increasing protein production is especially important. Production of meat from cropping in areas where such parasites as the tsetse fly prevent the development of a domestic livestock industry, or even the settlement of humans, is of interest to governments in affected developing countries.

Because wildlife in developed countries is generally of secondary consideration on agricultural lands, the multiple-use concept is advocated. This approach seeks ways to integrate production of wildlife into the primary land-use schemes devoted to producing food, fiber, and energy. The same principle holds true on extensively managed rangelands and forests. Economic benefit is always a principal consideration. In developing countries, wildlife also has economic importance. It must compete with other forms of land use and contribute to national goals along with food and other agricultural resources. On African rangelands, for example, game animals compete with and complement production from domestic livestock. Properly managed game animals in combinations with domestic livestock, and sometimes alone, can help maximize meat production from some types of land.

Wildlife management in practice consists of the following groups of activities:

1. Production of wildlife on rangelands, and the artificial propagation of certain species for hunting.

2. Conservation of examples of all biotypes and forms of life for scientific study, for the preservation of genetic diversity, and for the preservation and enhancement of the natural beauty of the world.

3. Protection of man and domestic animals from pathogens and parasites whose life cycles and host-vector relationships involve wildlife and rangelands.

4. Regulation of the numbers of predatory and noxious animals of economic importance to man's agricultural and industrial enterprises.

5. Production of food through harvest and marketing of wildlife from free-ranging populations in wild habitats, and the production of certain species, mainly large mammals, for meat in husbanded and cultured environments.

The first and fifth of these relate particularly to production from rangelands. The scientific aspects, assessments, and evaluations are other activities of people involved with wildlife.

The Hunting Resource

Hunting provides recreation and meat, and is probably the most important use of wildlife. Hunting has value and can be managed.

The tradition of sport hunting in many parts of the world, and surely on the African continent, developed from the time when lands were first colonized. Many people hunt for recreation and are willing to pay substantial sums for the privilege. Safari hunting reached its zenith in Africa and elsewhere during the two or three decades after World War II, and is still widely practiced. Consequently, many nations realize a substantial portion of their budgets from revenues attendant to sport hunting, which are often used to support their parks and wildlife-conservation efforts. Income is derived from the sale of concessions to safari companies, from licenses and other fees for taking various species of game, and from direct payments to landowners and native peoples for access to ranges where the animals occur. Without revenues from sport hunting, budgets for conservation and management of wildlife would be very small indeed.

Development planning must provide for the economic use of game animals. Different animals have different economic values. Animals that have little or no value (i.e., that are in conflict with domestic livestock and other agricultural interests, and that have no value as sources of food or hunting revenue) are likely to be eliminated.

Economic value can also have negative effects on conservation. For example, many indigenous peoples, especially in more primative settings, literally live off the land. Their weapons, while crude and inefficient, can decimate populations of animals. Poaching with snares, poisons, and guns is probably the most serious problem in the conservation of many species of wildlife. When animals have particularly high value as do elephants (ivory), rhinoceroses (horns), and zebras and spotted cats (skins), they are often vulnerable to concentrated poaching. Poaching with snares and other devices for antelope and smaller animals for food is also serious in many regions of the world. In some cases, extinction within a region of some species has occurred. On the other hand, poaching may be the most efficient and economic method by which surplus animals are provided to needy tribes and primitive peoples whose diets are low in protein.

The need for management for sustained yields is obvious, and needs more support. Careful appraisals of animal numbers and their values can provide the basis for harvesting without seriously reducing the breeding stock. Research, inventory, and operations to provide wildlife for sport hunting and for meat to local peoples are important responsibilities of governments.

Commercialized hunting has been quite successful in some places. One of the most highly organized and successful hunting enterprises is found in the state of Texas in the United States. About 350,000 white-tailed deer are harvested annually from a herd of nearly 3 million animals. About 60% of the harvest is taken under some form of lease or user-pay system.

The yield of meat approaches nearly 10 million kg, an amount larger than is produced from livestock in many developing countries of the world. The price of hunting varies with the abundance and quality of game; leases for hunting average nearly $10.00 per ha.

The European system of hunting is much more traditional and expensive, and game management is much more intensive than in other regions of the world. The quotas are carefully set, and individual animals are identified for harvest. The intensity of commercial management in Europe and the United States is in great contrast to management in many developing countries. In Africa, for example, the conservatism of early colonialist hunters reaches down to present-day safari hunting, and many populations of plains game and forest animals are underharvested. To reduce losses due to inadequate hunting or other causes, careful evaluations of increases in population and mortality rates must be made before quotas are set.

The importance of commercial or fee hunting cannot be overemphasized as a means to give value beyond the usual esthetic and cultural ones. These systems of commercial hunting stimulate production and protection of game, promote hunter safety, and distribute hunting more uniformly over game ranges. Moreover, commercial hunting reduces illegal killing and poaching by allowing hunters to take game animals legally. It may be an important avenue for the effective use of game in developing countries without adding a financial and administrative load to their governments.

Agricultural Interest

Conflicts between wildlife and agriculture often arise. As noxious or harmful animals, wildlife can be grouped into six categories:

- predators on domestic livestock
- depredators on crops and stored grains
- competitors with domestic livestock for forage and water
- reservoirs and vectors of diseases and parasites
- animals with noxious habits
- venemous and dangerous animals

Many animals that are classified as noxious or injurious in particular situations are highly beneficial and valuable in others. For example, African elephants can be extremely damaging to crops where they are forced out of reserves; in the reserves they are extremely important to the tourist industry. There are numerous instances where animals must be controlled or managed to prevent economic losses or danger.

The large carnivores of the cat and dog families often prey upon domestic livestock. In some places and at certain times, predation on sheep, goats, and cattle can reach proportions necessitating control programs. Overall losses may be smaller than costs of control, but catastrophic to the individual farmer. Prompt control or compensation to farmers is necessary to assure at least some tolerance of these animals in the agricultural community.

Certain birds, usually passerines and parrots, can cause extensive damage to crops in the fields, and to stored foodstuffs. Damage to cereal grains and to fruits and vegetables by birds and small rodents can be prevented or reduced by control measures and husbandry practices. Marauding elephants and herds of large, migratory herbivores can devastate croplands. Shooting of such depredators is sometimes the only solution.

Concentrations of birds in roosting flocks on buildings, in trees along streets and boulevards, and in agricultural outbuildings such as dairy barns have serious implications for man's interests. Often concentrations of various passerine (weaver finches, blackbirds, etc.) and psittacine (parrots) birds are so large that their excrement and filth kill the vegetation on which they roost. In milk houses and granaries, excrement, feathers, dead animals, and their filth pose disease problems to domestic livestock and to humans that use the agricultural products. When roosting flocks locate near runways and air approaches to airports, hazards to aircraft are likely. Weaver birds in Africa constitute a constant threat to grain fields and thereby constrain food production.

In spite of these negative examples, wildlife has a very beneficial relationship to agriculture. It is well known that birds and certain mammals assist in controlling insects and other invertebrates that are injurious to agricultural crops and livestock. Burrowing mammals turn the soil, and in doing so permit aeration and better percolation of water into the soil. Raptors (hawks, owls, and eagles) take rodents and lagomorphs (rabbits), thus controlling their population and reducing their influence on range and forest vegetation. Scavenging animals such as vultures and certain small mammals assist in keeping the landscape clean of decaying animals and prevent buildups of flies and other insects that lay eggs and pupate in carrion.

Livestock-Wildlife Relationships

In developing programs for livestock where wildlife is present, consideration must be given to the following relationships:

- competition between the animals for food and water
- effects of grazing pressures and systems of grazing on the animals
- effects of diverse animal species on overall utilization
- physical features of the rangeland provided by man such as fences, water, feeding, and perhaps burning

In addition to the four relationships listed, wildlife serving as a reservoir of certain diseases is also important, but has been discussed in a previous section. The competition varies according to the similarities in food preferences and according to the types of food available. One may obtain a rough indication of the degree of competition by simply assigning weights to wildlife and livestock. For example, six Grant's gazelles may equal in weight one grown cow; thus on weight alone, six gazelles equal one animal-unit equivalent of livestock. Obviously, the relationship is not so straightforward as this example implies because preferences for foods differ and food requirements per unit weight are higher in the gazelles due to their smaller size. Some large wild herbivores are grazers, others use woody species and fruits and berries. The great diversity of wildlife in the savannas of East Africa is possible due to differences in their dietary requirements. For example, elands and Grant's gazelles are predominantly browsers, Thomson's gazelles and wildebeests prefer short grass, and zebras seem to prefer intermediate grass, including stems. Giraffes select leaves and new growth from woody plants while elephants consume large quantities of coarse material. Most require some green material but others, like the zebra, do well on mature and dry forages. Figure 13 illustrates some habitat and food preferences of important wildlife species in Africa. When ranges are overgrazed, or choices are otherwise severely limited, diets of wild and domestic animals are practically the same. Under such conditions competition between and among wild and domestic animals can be severe.

On mixed grassland-brush habitats and range sites in the southwestern United States, animal-unit equivalents have been established for cattle, sheep, goats, and white-tailed deer. The equivalencies vary from season to season, and with range condition. However general they may be, they are useful in establishing stocking rates that include various species of livestock and game. In the U.S. study, the equivalent of one cow was six deer, or seven goats, or six sheep. These equivalents need to be established or adjusted to local conditions, and defined accordingly. Unfortunately, little is known about equivalencies for most wildlife species. This complicates the task of approximating an acceptable level of stocking for ranges with mixed game-and-livestock herds. However, initial approximations can be made that can be refined through continuing observations and experience. A high degree of precision in stocking rate may in any case be less important than capacity to adjust to changes in forage production.

Grazing animals, domestic and wild, influence the floristic composition and structure of plant communities and range sites in ways that serve the needs of other wildlife. Just as the various kinds of livestock have special requirements in range vegetation, so does each species of wildlife. No wildlife species can be expected to be a happenstance by-product of management for livestock. Their special needs must be taken into account. Most wildlife are obligate members of a particular seral stage in plant succession, and all have a habitat that best satisfies their needs. Grazing by cattle and other domestic animals can be used as a tool to manipulate vegetative succession to establish the seral stages required by particular species of wildlife.

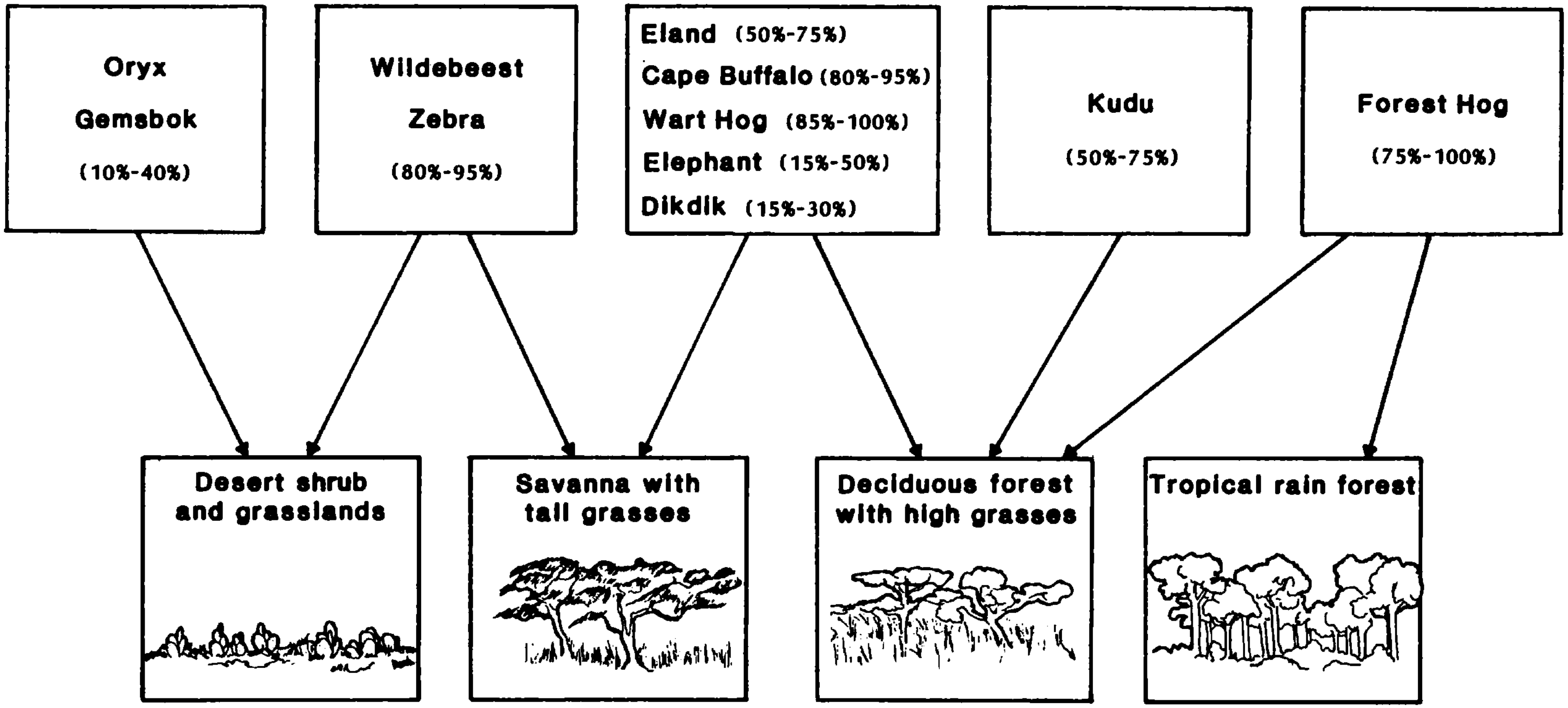

Figure 13. Preferences for habitat exhibited by selected African animals and estimates of percentage of grasses and forbs in their diets. Although wild animal species may occupy the same mosaic of vegetation, they do not select the same forages. Animal species further separate depending upon topography, wet or dry season, and even by feeding location within the vegetation. All the species tend to concentrate on the seasonally wet types in the dry season. Species in the winter rainfall and montane ecosystems exhibit similar patterns to those shown in the figure.

Physical improvement on rangelands must take into account the kinds of wildlife in the region. Fences are easily destroyed by many large mammals, and the provision of salt blocks, minerals, and water may be an expensive process when large herds of wildlife are in the pastures. Wildlife-proof fences have been used to prevent contact between buffalo and other wild herbivores and cattle, to stop the tick-borne spread of East Coast fever to cattle.

Large predators such as lions, leopards, and hyenas sometimes are a serious threat to domestic animals if not controlled.

Esthetic, Cultural, and Nonconsumptive Uses

Aside from recreational values derived from hunting and fishing, wildlife is extremely important as a source of relaxation and enjoyment. It is safe to say that many more persons are engaged in observing, studying, and photographing wildlife than engage in sport hunting and other consumptive uses. Such activities form the basis for tourism in those countries where wildlife spectacles and habitats have been preserved. Man has a natural curiosity about animals, and desires to satisfy this curiosity by observing them in their natural habitats.

National parks and equivalent reserves form the primary basis for the tourist industry because amenities are often provided for visitors and because the animals are relatively tame and observable. It is said that tourism in African states such as Kenya is one of the primary sources of foreign exchange. Many other countries have plans and opportunities for developing similar industries.

Not only do parks and reserves provide nonconsumptive recreation to an increasing army of tourists in the world, they also protect endangered species and germplasm that may have enormous potential for man and his agricultural and medicinal interests. They may also protect animals and cultural monuments that are important to the national character and heritage of a country. For example, the quetzal, the national bird of Guatemala, is protected in that country by parks. Without such protection, the bird would probably soon be eliminated because of the beauty and value of its feathers.

The values of pristine nature and ecological purity are heightened when man attempts to measure what has been and is happening to him in a fast-changing world. Reserves and parks contain landmarks and standards by which changes can be measured, and which can be used to interpret the intangibles that make up the quality of life.

All forms of wildlife are important as recreational subjects, some more than others. The tremendous migration of wildebeests in East Africa is an outstanding wildlife spectacle in a relatively untrammeled natural setting, and it ranks with such wonders of the world as the Taj Mahal and the Sphinx. These are world treasures contained within sovereign nations, which surely merit continued conservation. Song and insectivorous birds, reptiles, amphibians, and mammals are equally important in recreational and cultural values. For the most part, the public wishes to see them in their natural habitats.

Health-Related Interactions

Fully half of the amphibians, reptiles, mammals, and birds are in some manner, directly or indirectly, involved with diseases that affect man and his domestic animals. Furthermore, several species of snakes produce venoms that are capable of causing illness or death.

Rabies, arboviruses, and rickettsial, bacterial, and spirochetal diseases are groups of pathogens that have as their hosts or have in their life cycles some contact or involvement with wildlife. Modes of transmission to man often involve contact with infected animals or some vector such as ticks, fleas, biting lice, and biting flies. Zoonoses occur regularly in the world and the animals involved must be controlled. Poisonous snakes are believed to be responsible for thousands of deaths on the Indian subcontinent and are a danger in other parts of the world.

Game Ranching and Cropping

The economic potential of game ranching and cropping of wildlife from free-ranging populations of large mammals is still being evaluated in many regions of the world. Plains game (antelopes, zebras, buffalos, hippopotamuses, and even elephants) have been cropped in African savannas and forests. Large histricomorph rodents (capybaras, pacas, and agoutis) are harvested for meat in South America. A viable industry of cropping introduced deer in New Zealand and Australia has evolved into ranching of several species of deer for meat and antlers. In much of the world, animals of one kind or another are cropped in a systematic, organized fashion or are used by native peoples for food in systems that are best labeled "catch as catch can." At least 35 countries have a significant per capita consumption of game meat.

Southern African nations have a well-developed system of cropping of wildlife on ranches, and meat products are sold through the same markets as domestic livestock. While the industry is in no way as large as the livestock industry, it has been under way for some years. Most of the meat is marketed under the generic term "venison," and much of it is dried and sold as an exotic food or holiday fare.

Systematic cropping schemes in the great herds of plains game such as Thomson's gazelles, blue wildebeests, impalas, and Burchell's zebras have been attempted in East Africa, but these have not succeeded on any scale. Economic problems, competition from the livestock industry, and lack of good transport and refrigeration systems have impeded progress in this field. Combined game and livestock production is especially difficult for the herdsman with few animals and small landholdings.

Some herds of antelope, such as the wildebeest, which inhabit the Mara, Serengeti, Ngorogoro, and Loliondo regions of Kenya and Tanzania are now said to number about 1.3 million animals. Cropping of such herds could provide a substantial supply of animal protein without decreasing the value of the herd for tourism. Cropping might in fact increase the general health of the herd and increase reproduction.

Much of the meat that is marketed from wildlife in southern Africa and other countries is being sold in Europe. The greatest need, however, for such meat from wild populations is in the countries where it is harvested. That is because many of those game-producing countries have subsistence agriculture and people whose diets are heavy in carbohydrates, but inadequate in protein and fats. At the same time, successful cropping may produce foreign exchange important for the purchase of needed products abroad.

Game-ranching and domestication experiments with various kinds of wild animals have been conducted in many areas of the world. Usually these trials have been made with several antelopes of African origin. The eland, oryx, and several smaller species of antelope have been the most-used animals in ranching and domestication trials. Except for the eland, which has had some measured success for nearly a hundred years in and out of Africa, most attempts at domestication of game animals have not resulted in herds that were economically viable for meat production. Many countries have great interest in this effort because various species of antelope have diets that are fitted to vegetation not used as primary forage by domestic livestock. More concerted work in this direction deserves serious consideration.

New interest in producing leather goods from crocodile hides is being expressed in Asia, South America, and Africa. Crocodile and caiman farms are successfully producing leather goods for world markets. Specialty items such as musk from musk deer and antler velvet from various species of deer are also produced for medicinal purposes, especially for Oriental markets.

By and large, production of wildlife for meat and by-products in confined, husbanded conditions has not received sufficient attention for sound judgments about its future to be made. Long-term experiments are needed, and the farming or ranching of wildlife must be fitted to the cultures and lifestyles of the peoples of the region. Niche separation of the great many species of antelope in savanna ecosystems points to the process and probability of success with such experiments. The idea has merit for further research, especially in parts of Africa and South America.

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Chapter 4

Institutions

An understanding of the basic infrastructure in a developing country is essential to planning a range management project. Transportation systems, types of land tenure, personnel available, credit opportunities, and markets all impinge on range-development projects. In addition, many developing countries lack governmental agencies to handle management activities. Consequently, agency development should be an integral part of the development process for these countries.

Education and training components of development projects should be evaluated carefully. Often lack of provision for continued training negates long-term benefits for the project.

Training components of range-development projects may take many forms. In some cases only short courses or in-country training may be necessary, while in others B.S. or graduate degrees may be appropriate. For graduate work, research in-country that can be used for theses or dissertations at a foreign university may be the most beneficial mode.

Range Management Agency Development

Development Process

In many developing countries, clear policies and regulations regarding range use are lacking. Often policies have developed with a traditional "laissez-faire" attitude. Such informal policy results in uncertainties regarding access to water, dry-season grazing, etc., and places serious constraints on the livestock-production section.

In countries such as Yemen, where no agency to handle range problems exists, efforts need to be made to develop one. Initial steps may involve the establishment of a commission for initial planning and coordination. Later, interdepartmental work groups can be formed to set specific goals and objectives for the new agency. After the initial planning phases have been completed, agency establishment can be accomplished through legislative action or executive decree. It is important that the agency be given sufficient authority to make needed decisions concerning all range activities.

Agency Structure and Function

Provision of a single agency for planning and coordination of range activities is essential in any developing country with substantial rangeland area. In many instances range projects have suffered because no agency was charged with necessary follow-up responsibilities; often there has been considerable dilution of responsibility and effort in range management among several agencies.

Range management activities in many developing countries are administered through the Ministry of Agriculture. In some cases, rangeland is grouped with crops, usually pasture, while in others it is grouped with animal husbandry. In a few countries a separate department of natural resources also includes wildlife, parks, etc.

Planning for rangeland-development projects is discussed in chapter 6. To carry out such project planning effectively and to establish programs that will incorporate projects and other activities, an adequate institutional framework is essential. Only in this way is it possible to assure that continuity and corrective action will be taken as needed, as in Kenya and Somalia.

In Somalia the National Range Agency has a planning unit that is responsible for preparing a national plan for rangeland, forestry, and wildlife management, in cooperation with the Ministry of Agriculture, the Ministry of Local Government and Rural Development, and the Ministry of Mineral and Water Resources. The planning unit also helps the regional councils prepare their individual regional-development plans.

The next planning level in Somalia is in the Ministry of National Planning. This ministry carries out sectoral studies on livestock, range, and crop agriculture, thereby establishing the general guidelines within which development of each sector will take place. It also plays a basic role in defining national goals and policies essential for orderly development. In some countries, such as the Dominican Republic, all agricultural planning (including projects) is done within the Ministry of Agriculture.

For planning to be realistic and effective, a strong interaction between the technical and planning units is essential. In Somalia, for example, the planning unit within the National Range Agency is closely associated with survey, monitoring, research, and training. In the Dominican Republic the agricultural planning groups collaborate with technical staff in formulating programs and projects.

In addition to collaborating with technical staff, planners can facilitate implementation by helping to assure support for adequate staff and equipment by communicating agency needs to higher administrative levels, through policy development, furthering legislative support, etc. Planning units should also get feedback on implementation in order to improve or otherwise modify plans.

Projects for developing countries should consider the political and administrative context under which the project will have to operate. Failure to do so may doom the project to failure.

Regulation and Land Tenure

Many range people see the lack of land control as one of the major problems limiting livestock production in developing countries. Range improvement is hindered by a lack of control of grazing animals. Many range-improvement projects have not met their objectives because land policies are not sufficient to deal with the problems of: 1) gaining better control of the land and grazing (e.g., group ranches in Kenya and grazing preserves in Nigeria), and 2) working within traditional systems by making small changes that can be incorporated within the traditional systems. Often range projects fail because of lack of local involvement and lack of understanding of the local ecological and socioeconomic conditions by foreign advisors.

Land-tenure systems in Africa and other developing countries can be divided into three general categories: 1) those lands owned by a king, central government, or national authority; 2) those owned by tribes or a local government entity; and 3) those owned by individuals or families. Of course, there are many variants within these three general types. For example, in Ethiopia all land originally belonged to the king, who had the power to grant property rights to individuals. In Sudan, some government land is held with no local or individual rights relinquished, while in other cases rights are vested in a community, tribe, village, or in individuals. The communal land-tenure system in Sudan is complicated since there are 132 tribes and subtribes that move freely in search of stock water and green forage.

There is a need for land-tenure systems that reward responsible management as well as punish those who destroy the resources. The lack of such land-tenure systems, which often include grazing patterns, is considered a prime factor in the deterioration of range resources in developing countries. Each individual considers mainly his own gain -- and increases his herd size. This practice has the effect of increasing his income if the animals can be sold. However, this leads to overgrazing, which affects all users, not only the one primarily responsible for the herd increase.

Consequently, control of livestock grazing is an integral part of many development projects such as those involving the Nigerian grazing preserves and the Kenyan group ranches. However, Sandford (1983) argues that the "tragedy of the commons" analysis makes several unjustified jumps if it leads to the conclusion that private ownership is the answer. He also states that behavioral models used in the analysis may not be supported by anthropological studies. In some cases pastoral societies are capable of imposing rules on members of their society, which result in the necessary levels of control of livestock grazing patterns.

In any case, the impacts of changing traditional grazing patterns in development projects need to be evaluated carefully. The idea that nomadic or transhumant people must adopt sedentary lifestyles may not be tenable in all situations. Many alternatives may be available within the traditional systems. Such alternatives should emphasize practices that minimize conflicts and stabilize land tenure.

One traditional land-tenure-and-grazing system common in the Middle East is the "hema" system. Ahmia (plural of hema) systems are discussed in chapter 7. Under these systems, land and grazing is under local or tribal control, although earlier the governor of a state controlled the hema. The overall objective of the hema system is to provide forage reserves for livestock, especially in times of emergency such as drought.

Extension

Many developing countries have only limited extension services. In most cases the extension service does not cover range management; if a range-extension program does exist, it is often located in a different ministry than are research and development activities. And yet, effective extension programs may be among the most important portions of range-development projects. Extension programs have been effective in many countries and in all phases of agriculture.

Some of the problems that limit the effectiveness of extension are the following: lack of trained staff; difficulties due to inadequate roads and other means of communicating with a sparse and scattered population; too little information on which to base the extension message due to lack of research and other sources of information; unclear or mistaken program orientation (e.g., selling government approach without adequate concern for interest and needs of clients); and lack of understanding and appreciation of mores of local people.

While it is not possible to lay down absolute rules to be applied in all cases, the following guidelines are put forward for consideration.

- The orientation and focus must be perceived by clients as relevant to their problems and needs.

- Part of the extension process may be discovering the problems and needs jointly with the clients through meetings, discussions, and interviews -- and relating this to the larger picture derived from problem analysis, resource surveys, government policy, etc.

- From the preceding it follows that programs must have considerable flexibility and not be restricted to such a narrow field as to limit interest and participation. For example, range management could hardly be expected to interest the men, women, and children equally. However, interest could be increased by combining range management with other aspects of concern -- such as family, health, care of young animals, education, etc.

- Active involvement of the people should be given precedence over subject matter per se because involvement is perhaps the most important element in the solution of problems. Success at one level stimulates further ventures. Through this process competence for tackling the larger and more general problem is gradually gained.

- Informal approaches are best because they permit more participation than do formal approaches. Seeing and discussing are better than just discussing. A two-way exchange is better than a one-way lecture. For these reasons, field seminars and demonstrations are among the most effective methods to use in extension.

- Extension staff have to create the rapport needed. While this may be partly learned through training, it is also a special talent of some people. Finding people with the talent may therefore be more important than basing selection on other criteria -- such as level of education. Lack of knowledge is easier to correct than lack of talent. Knowing the local dialect and cultural setting is of obvious importance.

- The best kind of demonstration results from concentrating efforts so that there is a concrete and evident impact. As more staff becomes available, new areas or groups of people may be included -- but always with enough concentration to be effective. Continuity is another critical element of strategy; it allows the program to grow and develop as experience accumulates.

Research

Range research in developing countries should be aimed directly at or linked to the problems identified at the level of the pastoralist. Information on vegetation, soils, animals, and other ecosystem components is generally needed to meet these problems and other project objectives. Often it is possible to merge applied research and demonstration projects that also serve an extension function. The research may be beneficially done with the graziers themselves. Much of the work might be exploratory in order to more fully define the problems and to identify promising leads. Design of the research program should also take into account information needed to resolve policy issues. Some research areas that may be appropriate for range management projects are as follows:

- evaluation of present grazing practices and their influence on vegetation and other environmental factors.
- range animal management
- current production systems
- evaluation of forage reserves for drought and dry-season grazing
- range site delineation and condition
- vegetation classification and descriptions
- dietary analysis of major herbivores

These are only a few examples of the types of research projects that might be useful in range management projects. Long-term research might be handled best by the development of permanent research stations such as the Kiboko station in Kenya. Development of such stations involves considerable training and education at the M.S. and Ph.D. levels.

Research stations have several important functions, including developing and testing management practices that are technically possible and determining the applicability of these practices.

It is also important to evaluate management practices for appropriateness in the intended socioeconomic environment. Ten questions that should guide this evaluation follow:

- For whom is the research problem or constraint being investigated: producers, policy-makers, or simply other researchers? Who decides the value of particular research projects, and why or by what criteria? Research projects planned for people, as opposed to those planned with people, seldom succeed.
- To how many people is the problem or constraint considered to be important? Are the goals local, regional, or national? Do they meet USAID regulations for sponsored development research and implementation?
- Who would be the users or recipients of the results of the research?
- How much benefit will the users or recipients receive if the problem is solved? Quantifiable benefits aid in the decision as to which problems might be tackled first.

- What is the likelihood that the research will contribute to a solution to the problem? This may be evaluated on the basis of short-term or long-term results, capital-intensive or labor-intensive requirements, and low-cost or high-cost inputs, etc.

- Are research tools and personnel to solve the problem readily available? (Problems that can be solved with local resources are likely to have the most lasting impact.)

- What are the expected costs in time and money of solving the problem?

- Why is the proposed research problem or constraint being considered more important than some alternative that might be undertaken with the same resources?

- What is the expected cost of implementing the results if the research is successful? This is an important measure of appropriateness.

- When would benefits begin to be realized by the direct beneficiaries of the research, and who would benefit? In too many projects, the targeted beneficiaries are often forgotten in the enthusiasm of implementing the research, and it is mainly the researchers or project implementers who benefit.

Manpower Requirements and Disciplines

Specific manpower requirements for a project will vary depending upon the nature of the project. Some projects will require fairly large numbers of native technicians (as in extension programs); others will require only a few (as in research). In all situations, a structure should be established to allow manpower assessment and recruitment to continue after the termination of the project.

Often operation money is not adequate to meet all needs, and follow-up activities suffer. Recurrent costs should be considered and adequately covered in subsequent budgets. Many times government jobs are guaranteed for all those who complete specified training programs. This practice can lead to inefficient utilitization of people on projects since it does not guarantee a proper balance between disciplines. Alternate employment opportunities should be provided when possible.

Personnel

The number of trained range personnel in most developing countries is limited. For example, a current student from Lesotho at New Mexico State University stated that he would be the first from his country with a B.S. degree in range science. Since there are few universities teaching range management in developing countries, students desiring such education and training often must travel to the United States or other countries. Resources may not available to provide such opportunities. If trained personnel are not available, then someone with experience in pasture management or animal husbandry may fill in until appropriate people can be trained.

Working Conditions for Field Staff

Adequate facilities and living conditions must be provided if field staff are to effectively perform their duties. If such provision is not made, objectives are not likely to be attained. Incentives may be needed, perhaps in the form of increased salary or hardship allowances, in order to attract and keep field staff.

Logistical Support of Field Staff

If logistical support is not provided, project objectives are not likely to be met, even if all other aspects of the project are handled superbly. The project should be planned with full knowledge of transportation systems available, limitations of road systems, facilities for vehicle maintenance, etc. Most range projects require extensive field work and contact with local village people and tribal officials; however, roads may not be passable in the rainy season, and alternatives must be developed. In addition, modern accommodations are often not available, and workers must be willing to live and work under rather primitive conditions.

Transportation and Marketing

In most developing countries, transportation and marketing systems are poorly developed. Improvements in such systems will enhance range livestock production, but only if the improvements are in harmony with the available facilities and traditional modes of operation.

Migration Routes

Any market system that is devised for an area should take into account the local migration routes and livestock condition. In most developing countries, migration routes are relatively extensive. Maps showing these routes, such as those in Abercrombie (1974) and Thomas (1980), illustrate these patterns for areas in Africa. Normally cattle congregate around permanent water during the dry season, moving elsewhere during other periods of the year. Often these migration routes cross national or political boundaries. For example, Mauritanian herders often cross the Senegal River to allow their animals to graze in western Senegal. During the dry season, from November until July, livestock graze on perennial grasses of the floodplain along the Niger River in Mali. During the rainy season, when the river plain is flooded, the herds are driven to pastures in southwestern Mauritania.

Roads

Thomas (1980) reported that in the eight Sahelian countries in northern Africa, there is only 1 mile of road per 100 square miles of land. About 80% of these roads are either dry-weather, earth roads, or simply tracks. In countries such as Mali, Niger, and Chad, there is only one hard-surfaced road. Thomas (1980) listed the following roads for these countries:

Mauritania	6,000 km
Senegal	9,100 km
Mali	13,000 km (1,650 hard-surfaced)
Upper Volta	4,450 km (500 paved)
Niger	7,300 km (1,000 paved)
Chad	7,230 km (230 paved)

Other countries probably have more extensive road systems, but lack of roads remains one of the major deterrents to rangeland development.

Railroad Systems

The map of the railroad systems in Africa shown in Abercrombie (1974) illustrates the lack of rail transportation, especially in the Sahelian countries. There are virtually no railroads in southwestern Sudan, Chad, Libya, southern Algeria, northern Mali, Mauritania, northern Cameroon, etc. In other areas rail systems are not well developed. Thomas (1980) indicated that railroad equipment in Sahelian countries is adequate, but that the railroads are operated inefficiently and lend little assistance in the development process. Nevertheless, the railroads are important for some countries: 40% of Mali's exports and 60% of its imports are carried on the railroad connecting Bamako with Dakar, Senegal.

Airlines

In most developing cuntries national airlines serve the major cities. Most facilities could be upgraded, but fairly reliable air service between developing countries as well as to major cities in the world is available.

Finance, Banking, and Marketing

Financial and banking systems pose another constraint for agricultural development in many developing countries. Even if adequate systems are available in urban areas, they may not be known or available to livestock operators in rural situations.

Currency Systems

Most developing countries have their own currency, although several West African countries have a common currency. In some of the rural areas currency is replaced by a barter system. However, currency is still used at many trading posts; hence markets are necessary for these people to obtain currency to purchase certain needed supplies.

Credit Opportunities

Credit opportunities are limited in most developing countries, and the development of credit is fraught with several problems (Moris, 1981). Some economists visualize the availability of credit as a necessity for rural agriculturalists to break from the mold of subsistence farming and livestock production. Often efforts to develop credit systems for agriculturalists who are not on a cash economy have not been successful. The lure of credit may be used to stimulate the adoption of new technology, build managerial skills, and improve business management, but this approach also creates problems. Most small-holder agriculturalists lack the managerial skill needed to plan their cash flow over an entire year when sales are made only once per year. Loan defaults create problems in developing countries. The situation is somewhat similar to a "catch 22" scenario. Small farmers and livestock owners need credit the most to help stabilize their operations, but are the least likely to be able to manage their finances and hence the most likely to default.

Moris (1981) listed the following conditions for successful credit management in developing countries:

- monetized agricultural system
- input-delivery system working with reasonable efficiency
- loans secured against producers' credit records
- producers with reasonable managerial ability
- some local organization to handle marketing and loan payments

Markets, Imports, Exports

A lack of adequate markets is often cited as one of the major limitations to livestock production and management in developing countries. However, the traditional western marketing system may not be applicable to nomadic or even sedentary pastoralists in developing countries. The reasons for possessing livestock involve the immediate needs of the tribe or family (for milk, meat, hides, etc.), for accumulated wealth or prestige, or for religion. People like to maintain large herds as a hedge against drought. With a large herd, the probability of a viable number surviving a severe drought is higher.

In many African countries agricultural products do not bring a price to the producer that is commensurate with existing world prices. Reasons for these depressed prices are many: export taxes, marketing costs, overvalued exchange rates, lack of local price incentives, and pricing policies to favor local consumers. Such practices hinder the development of markets. In cases where livestock are kept primarily for prestige or for milk, hides, and meat for consumption within the tribe, development of markets is not so critical. In other cases, villages and tribes may be dependent upon livestock markets to provide money for millet or other grain for the village or family to subsist during the dry season. Such is the case for some tribes in Niger and Upper Volta.

Market systems in developing countries range from bartering to well-developed national markets for commercial ranches. With this range of variation in market structure, it is critical to evaluate both existing and proposed market systems for any development project.

Transactions in village markets are typically conducted through intermediaries who are familiar with both the demand and supply sections of the operation. Someone wishing to buy livestock contacts an intermediary, who tells the buyer which producer has animals of the type needed. The intermediary receives a commission from either the buyer or the seller.

In many countries markets are controlled by the government or by quasi-governmental organizations, such as state trade organizations with licensed buying agents. In West Africa, market days are established at regular intervals and livestock are brought to the local markets where buying agents are present. Marketing organizations in developing countries are responsible for the collection, transport, and distribution of livestock, but are generally inefficient.

In areas where commercial ranches are becoming established, markets that can handle the projected volume are essential. Often larger markets are developed near population centers where facilities for processing and shipping are available. Some authors have recommended that fat, dry cows and hair sheep be marketed through local butchers, and better quality beef, lamb, and mutton go to state organizations such as the Kenya Meat Commission, Tanzania Packers Limited, or the Uganda Meat Packers.

Education and Training

Training Needs

Developing countries need a continuing supply of range technicians. Training is needed at all levels to accomplish this, including the doctoral, master's, bachelor's, and associate degrees, as well as shortcourse training for administrators of range-science programs who are not trained range managers or scientists. There is an obvious large discrepancy between the needs of trained personnel in developing countries and the supply. One example illustrates this need for more trained people. Surveys indicate that by the year 1988 there will be a need for 188 certificate-holders, 53 with diplomas, 80 with B.S. degrees, and 12 with M.S. degrees in the Ministry of Agriculture in Kenya. For the Ministry of Agriculture, other ministries, and commercial concerns, the total requirements would be for 279 persons. This represents an increase of 159 over those in these positions in 1977.

Kenya has placed major emphasis on range training with the development of range curricula at Egerton College, the Animal Husbandry Institute for Tropical Agriculture (AHITA), and the University of Nairobi. The situation in other countries with no range curricula is much more serious. Many development projects throughout the world have a training component to furnish personnel for the projects. However, seldom is there provision for training once a project is terminated. Thus, projects such as those in Somalia and Morocco to develop range management curricula are critical.

Initial attempts to improve range management practices in developing countries have met with difficulties in large part due to the shortage of qualified range management personnel and the problems that available specialists have had in involving pastoralists in decision-making processes. This experience has been repeated over and over again.

Range-development projects should not be attempted without substantial host-country participation. Outside advisers will never understand the inner workings of another society to the extent that it is understood by local technicians. The necessity is to provide these technicians with the best training possible, allowing them to make technical adjustments to fit cultural needs. The ultimate goal is to help developing countries to be self-sufficient in their range-improvement efforts. Various training approaches can be used to accomplish this.

In-country Training

A growing number of people are advocating training by experienced range-science educators, whether native or foreign to the country in question, in the setting of the host country. The principle of this approach is laudable as it forces presentation of applicable material, and it gives the trainee immediate tools that do not need reshaping for home use. It does not, however, adequately prepare him to adapt findings from other countries as the science develops in his country.

The lack of available, qualified professors of range science who can lecture in a language other than English is a critical limitation. In addition, until foreign educators are provided with some sense of job security, they will rarely be attracted to the short-term sporadic opportunities that now exist. Even when qualified individuals occasionally are available, they often have not had time to prepare for their assignments. The result is that their presentations may be little different from those presented in classrooms in their home country.

The difficulties that arise from the lack of trained personnel are compounded by the lack of adequate training sites in developing countries. In order to teach principles of optimum management, areas managed at an optimum must be present. These field facilities are presently much more limiting than adequate classroom and laboratory facilities.

There are universities in developing countries that provide instruction in range management. The University of Nairobi has developed a B.S. curriculum with plans to initiate graduate programs, as has the Hassan II Institute of Agronomy and Veterinary Medicine in Rabat, Morocco.

Sudan, Somalia, Iran, Peru, Jordan, Botswana, Swaziland, and Niger, to name a few, provide range management coursework within their undergraduate agricultural or natural resource degree programs. Many countries provide pre-B.S.-degree training at the certificate or diploma level. Such schools include Egerton College, Njoro, Kenya; the Animal Health and Industry Training Institute, Nairobi, Kenya; and the Livestock Training Center, Kaduna, Nigeria. The latter school is a branch of the Ahmadu Bello University, with the main campus in Zaria, Nigeria. These schools are singled out here simply to demonstrate the interest in range management education. Their graduates are accepted into B.S. programs elsewhere with varying stipulations. Some programs are strong in animal science, others in plant taxonomy and ecology.

Degree and nondegree programs organized by personnel from developing countries and conducted in a developing-world setting are the ultimate goals. Until adequate programs exist in the developing world, however, the personnel who will eventually develop and staff these programs must be trained outside the country. Some countries have recognized this need and have developed their own extension, formal education, and research organizations; thereby ensuring adequately trained personnel to maintain their range institutions.

Out-of-country Training

The training component of range management projects all too often is characterized by a scenario that starts with a training program in the United States, where a maximum of one or two counterparts are trained for each American project specialist. This arrangement frequently includes one or more of the following failures. 1) Counterparts do not return from the United States until the project is finished and thus they never have the opportunity to work in the field with the specialist. If 6 months to 1 year is required to identify potential students and have them cleared and approved for training in the United States, and 2 to 4 years for a B.S. or M.S. degree, it may take nearly 5 years before the candidate is ready to assume his position within the project. It is important in designing range projects to provide sufficient time for the student to work in his assigned position within the project for a year or more before the project is terminated. 2) These trained developing-country nationals may be assigned to other projects that lack a training component. This reliance on other projects to supply trained manpower results in a self-defeating cycle of training deficiency. 3) Counterparts, once trained, often leave the project for a more lucrative career in private business or in another country.

One possibility to counteract the time limitation might be to begin the training phase 1 or more years before full-scale project activities start. An early training phase, including mastery of a second language, could be an integral part of the training programs included in most AID missions and could be underway throughout the lengthy planning process of AID and other organizations as described in chapter 6.

In order to establish sufficient numbers of high-caliber persons in key positions, effective training requires a mutual long-term commitment that anticipates the high attrition rate caused by the factors noted above. However, whether personnel move to other projects, to private industry, or to administrative government positions, rangelands will benefit in the long term from the influence of these trained range scientists.

Degree Training

Those who advocate training in established U.S. range-science schools do so primarily because of the successful history of the U.S. model in agriculture. The critics, however, point out that the U.S. system of education is aimed at a different audience, with different cultural backgrounds, perhaps different motives, differing incentives, and in an economic structure dissimilar to many parts of the developing world.

Training programs for foreign students in range science in the United States are lacking in both quantity and quality. We have known for some time that classroom teaching has not been directed toward foreign students or toward developing-world problems. It is directed at future managers of U.S. land. Orientation and preparation of degree-seeking foreign students is extremely variable -- often inadequate -- prior to entering scholastic programs. Few U.S. university faculty have had the opportunity to gain international experience by living in a developing country, which would prepare them to direct training activities for such a country. For these reasons it has been difficult to coordinate training activities, either for an individual or for a country.

However, until range scientists become linguists, until qualified range-science professors are attracted to institutions in developing countries, and until foreign training sites and facilities are developed adequately, it appears that the most feasible method of improving training for foreign students is to adapt U.S. materials and presentations to the needs of foreign students and to illustrate principles with examples, both good and bad, in relevant rangelands of the world. For example, Utah State University provides a special B.S.-degree program for foreign students in range science and has developed regular seminars and special courses in range ecology, range improvements, project planning and implementation, pastoral societies, and special problems in extension, directed toward U.S. and foreign students who plan to spend their careers in international development work. Other universities have developed special courses to meet the needs of international students.

Selection of a U.S. university should be done with care. It is important that the university have a program appropriate to the candidate. Choosing a school with an environment somewhat similar to that of the home country is also a consideration for two reasons: 1) Research conducted in a similar environment may be more relevant than that conducted in a dissimilar environment; and 2) it may be easier for the student to adjust to an area with a similar climate.

A modification to out-of-country graduate training, which has been used in several countries in the past 10 years in collaboration with various U.S. universities, is to have the student complete the academic portion of his program at a U.S. university and his research in his home country. Such a program can require more time and be more costly than the traditional pattern of university research. Benefits include the development of a research base in the home country that can help solve problems there and, most importantly, that can provide experience in working in local environments and under local constraints. The approach requires adequate supervision of the research conducted in the home country either by host-country scientists or the adviser from the out-of-country university.

Although the approach of early out-of-country training has been taken in many developing countries, the goal has been for the country or the region to become self-sufficient in its training of range scientists in the shortest time possible.

Self-sufficiency requires that people from the developing country trained to the Ph.D. level establish research and formal training capabilities within their home countries. The demands for these trained people are numerous and are rapidly increasing. There are many situations, however, where Ph.D.-level training is not necessary. The majority of the administrative positions would be best filled with M.S.-level personnel trained in administration, personnel management, extension technologies, or cultural anthropology, in addition to basic principles of range science. Since range management is a broad discipline drawing on many other areas, emphasis on specific topics can vary considerably. Often such training includes grazing management and livestock production, but with little emphasis on extension techniques. The nonthesis approach available at most U.S. universities allows this type of training, carries the equivalent of a research degree, and is being used by countries that have assessed their total needs.

Nondegree Training

In many countries agricultural technicians have received training at the Ph.D., M.S., B.S., and associate degree levels. Unfortunately, it is the associate degree that receives the least attention, yet people trained to this level are most active in taking research knowledge to the livestock producer.

Particularly in the initial stages of developing a technical speciality in any country, the contact between B.S.- or higher-degree-trained technicians and livestock producers is minimal, due primarily to the administrative duties inherent in any organization. Local field-level technicians will always have the most frequent contact with producers. If this level of trained personnel does not exist, or if their training does not include range management and extension principles, the means by which research findings can be transmitted to the producer, and subsequently applied, are greatly limited. It is important that this technician be capable of communicating with the local producers. This is not the place for the "outside expert." Frequently field-level technicians in developing countries who have been assigned range management duties are members of a different tribe or family group than that of the local producers with which they are working. This makes these technicians "outside experts" also.

An additional need is for nondegree, shortcourse training for administrators who are responsible for introducing, implementing, and evaluating range management projects but who have no formal training in range management.

Shortcourse training provided in the United States has failed to focus on developing-country problems, has not been sufficient in covering the principles of range management in either breadth or depth, and has not included adequate training in extension methodologies.

The need for short-term nondegree training in range science has been expressed for a number of years by institutions involved in development programs. A variety of courses have been established that will meet these needs. It must be noted, however, that these should be used only so long as quality programs and facilities do not exist in appropriate developing countries.

Shortcourses have been offered by FAO in Arusha and Tanzania, and in Egypt for the few years in which it had a range project in Egypt. FAO has no ongoing shortcourse training program due to the lack of a permanent arrangement with qualified faculty.

In-country range-science training that is offered by the Consultative Group on International Agricultural Research (CGIAR) is limited to the International Center for Tropical Agriculture (CIAT), the International Livestock Centre for Africa (ILCA), and the International Center for Agricultural Research in Dry Areas (ICARDA). Training at these centers is primarily intended for updating and strengthening capabilities of those who have a sound foundation in science.

The International Training Division of the Office of International Cooperation and Development (ITD/OICD) of USDA offers an annual 9-week (June and July) course entitled "Range Management and Forage Production." It is presently offered in English at New Mexico State University. About one-half of the annual participants are in the United States for short-term training only; the other half are in degree programs. This course is designed for range and livestock officers, extension specialists, teachers and professors, technicians, and farmers. Participants study plant identification, vegetation types, mapping and range survey, determination of range carrying capacity, grazing-use patterns, forage utilization, reseeding for improved and increased forage production, control of undesirable weeds and bush vegetation, water development, and fencing. The format is one of seminars, workshops, and field visits.

USDA offers three shortcourses that have some application to range science but that do not teach any formal range management subject matter. These 6- to 9-week courses are:

- Land-Use Planning in Natural Resource Management: Integration of Natural Resource Management and Food Production

- Small-ruminant Production Techniques
- Seed Improvement

A wide array of extension methodology in shortcourses on management, education, human resource development, and others that could usefully fit into a range-science training program, are offered by USDA. These include:

- Communications and Media Strategies for Agriculture and Rural Development
- Development and Operation of Agricultural Extension Programs
- Training of Trainers for Agriculture and Rural Development
- Initiating and Managing Integrated Rural Development Programs
- Keys to Agricultural Development at the Local Level

Economic and policy shortcourses offered by USDA, relevant to the majority of range-science trainees, include the following:

- Project Analysis for Agriculture and Rural Development
- Establishment and Management of Agricultural Cooperative Organizations
- Project Planning for Agriculture and Rural Development
- Project Implementation for Agriculture and Rural Development
- Effective Livestock and Crop Management for Small Farms

In addition to the courses enumerated here, USDA offers a number of other shortcourses designed for higher-level administrators and research personnel, as well as technical courses in academic disciplines other than range science.

Individual projects of USAID, FAO, and the World Bank also hold occasional shortcourses for their own personnel.

The administrators' shortcourse offered by the range science department at Utah State University is provided for two kinds of participants: first, administrators and government officials responsible for introducing, implementing, and evaluating range management programs in less developed pastoral areas; and second, professional staff in consulting companies who are engaged in development projects on rangelands. The shortcourse assumes that the participants have not had prior formal education in range science. Special attention is given to the problems of rangeland-development projects in developing countries.

The need for practical, hands-on training both at a degree level and for nondegree technicians is obvious. Individuals selected for this type of training, however, typically descend upon a range science department or a government agency with little advance notice and no well-defined goals for their program. The result has been incomplete training that competed with the already full schedules of professional employees.

Utah State University has developed a 6-month, practical-experience shortcourse in range management and extension principles. This shortcourse is designed for technicians and extension agents who have a background in agriculture and(or) animal science but have had limited or no training and experience in range management and extension. The philosophy of this short-term training is that, in appropriate instances, learning through "hands-on" experience is the best method. This experience is gained by working individually with a rancher, a county agent, an experiment station technician, etc. The participants receive additional technical training from visits to research stations and attendance at other range management shortcourses and workshops. A coherent overview of range and ranch management in the context of developing-country problems is provided in such a way that participants obtain a perspective of the components of range management extension they might apply in their home country. The shortcourse is taught and coordinated by personnel with long-term experience on international projects.

The ranching experience is a vital component because it allows the participants to gain first-hand experience of management systems. The schedule is such that the trainees are able to actively participate in the major operations of sheep or cattle ranching. At the beginning of the shortcourse, each participant is assigned to a ranch at which he works during predetermined and intermittent periods throughout the short-course training period.

The technical training is aimed at improving the participants' knowledge and understanding of range ecology and management. Without this basic training, they would not understand much of what they observed in the field with the ranchers or extension personnel. The technical training is divided into three parts: 1) an introduction to range management and ecology in a classroom atmosphere; 2) more advanced training consisting of visiting and working on experiment stations in California, Idaho, Utah, Arizona, New Mexico, and Texas; and 3) providing space is available, enrollment in USDA's Range Management and Forage Production Shortcourse at New Mexico State University.

On-the-job Training

One school of thought concerning where and how training might be accomplished concerns on-the-job training (OJT) in the trainee's own country where the trainee is a "counterpart" to a foreign expert. Support for this method in this country has grown out of the realization that without it the U.S. professor has little opportunity to teach in another language, to understand another culture, or to attempt to adapt western technology to another setting.

The tendency to rely entirely upon on-the-job training for counterparts is unfortunate, because the inadequacy of such training has been shown throughout the history of development assistance. The average foreign expert on the production-oriented projects that dominate foreign assistance has seldom had the teaching experience necessary to impart the sound background in the basic sciences that is essential for an appreciation of the principles of range science. And unfortunately the counterparts do not necessarily develop a thorough understanding of these principles simply by participating in OJT.

Most of the effort is aimed at achieving a certain goal -- a fence built or a stock pond dug. Why and how these jobs are done is seldom explained in detail if at all, and training is given only to the extent necessary to accomplish the immediate task. The underlying principles of plant physiology or animal nutrition, or other options open to accomplish the objective, are seldom thoroughly explained. OJT is normally limited to one trainer per trainee, as opposed to an entire faculty from whom one could receive these explanations in a formal training setting. Counterparts commonly change so often that no continuity in OJT is possible, nor is any aspect of training followed to a logical conclusion. A one-on-one training experience is very demanding, requiring long hours and patience. Both the trainer and trainee are prone to take advantage of distractions that too often result in the trainer and trainee spending little time together, and the trainee is expected to have gained more than was possible.

More conscious emphasis on training as a project objective and close program supervision are necessary to overcome this problem. What needs to be done is to maximize the impact of each expatriate professional. There is no reason why each expert should not be working with several nationals -- and this has been done successfully in various projects. More use should also be made of organized seminars in order to stimulate participation in intensive shortcourses, etc. In short, OJT can be successful and highly productive if it is planned and carried out with the same dedication as other project objectives.

After years of training overseas, however, it can be difficult for newly returned technicians to put expertise to work in the field. This is partly the result of long-term cultural isolation. In addition, trained nationals are often not from the traditional society with which they are working, and also have cultural barriers to bridge. As a complement to sponsorship of overseas technical training, additional in-country consultancy support to newly returned range technicians is necessary. Those who have received formal training would likely benefit more from short expatriate consultancy visits.

In fact, funds spent on long-term foreign technicians living in developing countries would often be better spent on more frequent and diversified consultancies and on organized formal and informal training programs. This does not mean that developing countries should isolate themselves from the rest of the world. Current and future range scientists must maintain links with the world bodies of range science through membership and attendance in meetings of the Society for Range Management, Australian Rangeland Society, etc. They must exchange their knowledge and new findings with each other by forming their own range management organization, by conducting regular technical symposia, and by becoming active in publishing range-science information, either in existing technical journals or in a journal that they create. The industry of range management in any country also needs exchange with foreign experts in the form of consultancy visits, collaborative research, etc.

Library Facilities

Libraries of rangeland resource materials are scanty in developing countries. Universities where range courses are given and experiment stations normally have all or most issues of the Journal of Range Management and a few books. However, most overseas bulletins and more practical publications are lacking. Students and visitors to developed countries, mainly the United States and Australia, usually accumulate a small library of their own, but most persons find these difficult to keep up-to-date after they return to their home country.

An important service of most natural resource projects is fostering the accumulation of library materials. Procedures could include budgeting for 15-year or longer subscriptions to appropriate journals, with their depository stipulated as a library or some other permanent location. Neither a 5-year project headquarters nor the directorship of a study is sufficiently permanent. Libraries should be placed by resource projects on mailing lists of state and federal experiment stations in developed countries. Advertising for donation of personal libraries can be helpful, but in most such donations the proportion of old and out-of-date material makes them of questionable value. Whatever the procedure finally chosen, enhancement of libraries should be planned from the preplanning and assessment stages through the post-project follow-through. Enhancement of country libraries, not private acquisitions, is the goal.

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Section II

Rangeland Interventions

Section I describes the elements of rangeland systems; Section II describes the processes and interventions that can contribute to the attainment of the long-term needs of people who depend on such systems. The three chapters in this section discuss the assessment of rangeland resources, planning for the integrated management of these resources, and the concepts that underlie successful rangeland management. The objective is to give recommendations on major approaches and to leave specifics to the companion volume on design aids.

Chapter 5

Rangeland Resource Assessment

The theme of this chapter is that the assessment of rangeland resources must be an integral part of a rangeland-resource-development-and-management project. Assessment encompasses two important functions: 1) the inventory, analysis, and interpretation of information to be used in planning and 2) the monitoring of the effects of plan implementation to ensure success. Abiotic, biotic, and institutional factors are discussed. The reiterative role of assessment is explained in each of five phases of the development process. A strategy is outlined to achieve essential unity between resource assessment and development planning. The chapter concludes with a listing of four measures that will ensure beneficial use of assessment results.

Introduction

Concerns of Resource Assessment

In rangeland development and management the concern is with human manipulation of the ecosystem in regions of the world that are mainly valuable for the production of human food, as watersheds, and as habitats for domestic and wild animals. As described in chapter 1, such areas include the desert shrub and grasslands, savannas with tall grasses, deciduous forests with high grasses, tropical rain forests, montane forests, Mediterranean winter rainfall vegetation, and seasonally flooded and wetland vegetation. To conserve these lands and to improve their productivity, it is essential to understand their ecological characteristics and interrelationships, their productive potential, and the natural limitations on their sustained use. Resource assessment contributes to this understanding and relates it to human goals so that wise decisions can be made. In this chapter the expressions "resource inventory," "analysis," or "assessments" will generally be used in preference to the more limiting "rangeland resource assessment."

The development and management of rangeland resources involves the manipulation or modification of ecosystems. This requires an inventory and analysis of 1) the resource base (vegetation, soil, and water), 2) the human and animal users of the resources, and 3) the existing infrastructure for economic development. Such an assessment will serve most of the needs for planning in land-use areas other than those used for grazing. For a comprehensive discussion of resource evaluation, the reader is referred to "Resource Inventory and Baseline Study Methods for Developing Countries" by Conant et al., 1983. The chapters on soils, plants, and wildlife have considerable information relevant to rangeland assessment and management.

An ecological assessment for integrated resource use, as explained in chapter 6, will usually provide more information than any of the alternative land uses may individually require. It also provides more of an in-depth understanding of the ecosystems than governments and people in most developing nations may be able to use immediately. This conflict between what is needed and useful and what is essential for an integrated land-use approach to resource development raises some serious questions that must be objectively answered as resource-assessment projects are planned. While the tendency is to create an information "overkill," there are practical solutions to the dilemma. Some of these are covered in the design aids volume.

Resource Assessment in Developing Countries

Relationship between assessment and development planning. All too frequently, development projects are conceived, the project location decided upon, and goals set without knowledge of the condition and extent of the resource, its potentials and limitations, or how the people affected by the project feel and what they know about their natural resources. In other cases the assessment is treated as a separate and isolated project, concluded and reported without reference to a specific development program. In both instances, the projects are likely to be misguided, and thus fail.

Chambers (1980), in discussing information for rural development, wrote: " ... rural development ... [is] ... like voyages into uncharted seas where direction and steering will change with new soundings and sightings." If these measurements are not continuously made throughout the voyage, disaster will be inevitable. Such is the relationship between resource assessment and resource development and management.

Commonality of goals, people, and government. In developing countries, a strong difference often exists between pastoralists and agriculturalists and government officials, including local and regional leaders. The people on the land tend to be survival-oriented, while the governmental leaders tend to be economically or commercially oriented. These divergent orientations are difficult to meld into a set of mutual goals for which everyone is willing to work. Success will largely depend on how well the planners for the donor nations and the host governments understand the people and communicate with them, the natural resource base, and the actual relationship between the farming and pastoral societies and their environment. Resource assessment can provide the information necessary to such understanding.

Multiscale resource assessment. Resource assessment is a reiterative process. Each iteration progressively refines the maps, data, and information as progress in development is made and the need for information intensifies. The first information often needs only to provide orders of magnitude and direction of change to meet the policy, objective-setting, and broad planning needs. This is followed by a more detailed assessment as the need for more refined or localized decisions becomes evident.

In the rigorous and sparsely settled environments of arid and semiarid rangelands, most planning needs are met by a generalized ecological assessment that maps ecosystems at a scale of 1:1,000,000 to 1:200,000. One of the main purposes of such an assessment is to identify the specific landscapes of high resource potential where more detailed inventory and assessment are needed. These smaller, high-priority areas would rarely need to be analyzed at a scale larger than 1:50,000 to 1:40,000 in developing countries. This two-step approach is cost effective because it allocates financial and manpower resources in proportion to resource quality and potential. It is also consistent with progressive planning from national, to regional, to local levels.

Program needs. In the majority of developing nations, there are a number of requirements for progressive rangeland-resource assessment. These include: institutions or agencies capable of accepting accountability for rangeland-resource development and production; grazing-land policies and national and regional objectives for development and management; national, regional, and local allocation of resources among land uses;

and finally, the custodial and eventually the more intensive management of animals and rangeland resources at the local level. The information needs for this progression of actions match exactly that provided as one progresses from the first-look, small-scale national and regional assessment to the larger-scale assessments used to plan and implement local management projects. At each step, the fundamental questions should be:

> What information is needed and what kinds of information can be used?

and not

> What information can the technology supply?

Assessment planning based on the latter question results in a mismatch between information needed and that provided by the assessment project. Furthermore, an approach oriented toward acquiring **usable information based on realistic needs** often results in surprisingly uncomplicated and highly cost-effective initial assessments.

Central depository for resource information. In support of resource-assessment-and-development planning, donors and recipients should give serious consideration to the creation of a central library in each developing country for storage of resource information where it could be readily available and permanently protected. A small library staff must be trained so that the facility can be maintained and kept up-to-date as new information becomes available. Information collected should include copies of all relevant studies by colonial governments and United Nations agencies, donor-agency reports and special studies of natural resources, inventory maps and tabular data, and scientific studies on renewable natural resources -- especially on plant taxonomy and ecology, geology, water resources, soils, and land-use capability.

Lack of this kind of library in developing countries results in countless hours lost, inadequate planning, needless repetition of work, and other costly deficiencies. Much of the good work from the colonial days is on deposit in the home files of the former colonial government. In-country copies often have been lost or absorbed into the private collection of an expatriate advisor or a government official. If not retrieved and organized, they may be lost forever.

Activities in Resource Assessment

In its simplest terms, resource assessment is a four-phase task: acquiring the data/information, analyzing and reducing the data, relating the data to the purposes perceived in the planning of the assessment project, and later reinterpreting the data, possibly with acquisition of supplemental information, for needs not perceived in planning.

Terms used to describe the activities that take place when one makes a resource assessment are "survey," "inventory," "analysis," "interpretation," "assessment," and "monitoring." Survey and inventories relate to the delineation of the kind, characteristics, productivity, condition, and value of the resource. Results are normally presented in mapped or tabular form with or without narrative explanation. Analysis involves primarily the examination of the data, to reduce, summarize, and tabulate -- to sort relevant from irrelevant. Interpretation strives to explain the meaning of the information in understandable and relevant terms; to draw inferences from the data that are relevant to questions planners ask of the database; and to point out which facts support and which nullify certain conclusions, assumptions, or alternative decisions. For example, statements of land-use suitability or of ecological potential are interpretations based on the factual results of the resource survey and analysis. Assessment is an inclusive term that covers all of the above. But more specifically, assessment involves making an official or professional valuation that relates the information to specific decisions that may be made. This process involves selection of alternatives that will solve specified problems or achieve stated goals and objectives. The assessment functions are thus carried out prior to and concurrent with the planning process. Once action is initiated on a project, the same sequence is referred to as monitoring -- a process of assessment for the purpose of adjusting and improving the program and detecting unanticipated side effects.

Range resources are surveyed and inventoried to obtain information that is only as reliable as is necessary for the stated objectives. For example, the emphasis of methods selected for the inventory might be on accuracy. Monitoring, on the other hand, involves measurements or estimates made over time to detect changes or responses to management. Since several people may be involved in these evaluations, precision or repeatability of measurements might be more important.

Resource Assessment in the Development Process

Resource assessment is essential in three of the five phases in comprehensive planning (identified by asterisks below) and has an important role in the remaining two:

*preplanning for resource assessment
*information acquisition and analysis
 planning the project
 implementing the project
*monitoring and follow-through

Preplanning for Resource Assessment

For the first phase, information acquisition involves data that are relevant to a) assessing the situation, b) performing initial problem analysis, c) setting goals and objectives, and d) identifying new information needs. The latter provides the framework for the actual assessment project. Preplanning for resource assessment therefore includes the assembly, organization, and indexing of the existing database, plus the analyses required to achieve a), b), and c). Following are some conditions and options that must be considered in this first stage.

Resource assessment may proceed in three ways: 1) interviews and skilled observation, with limited mapping, by an individual or a team of experts; 2) a single-purpose survey or inventory (e.g., to meet range management or agronomic needs only), or 3) an integrated ecological analysis intended to service projects in several land-use or technical-development areas.

Frequently the ability to use information and the capacity of the government and the people to respond to development and management recommendations is too limited to justify the collection of sophisticated and highly quantitative data. In this instance, a small, highly skilled team of experts might, by strict observation and interview methods, rapidly develop all the information needed for initial planning.

The single-purpose assessment rarely meets the needs of any but the immediately intended application. Its focus is such that all secondary needs have to be met by an entirely separate survey or inventory, which often duplicates part of the first.

The comprehensive ecological assessment, on the other hand, may result in a temporary information overkill, and yet may fail to make some of the detailed determinations required for a particular resource use. The integrated ecological assessment treats all elements of the ecosystem--climate, vegetation, landforms, soils, water, animals, demography, social factors, infrastructure, governmental organization, and policy. Such a comprehensive analysis is required when planning for "integrated resource use" as discussed in chapter 6. In addition, the thorough ecological approach establishes an environmental stratification for subsequent observation or sampling. This increases efficiency and reduces the costs of all the supplemental inventories and assessments that individual projects may require.

Each of these alternatives has a set of advantages, disadvantages, and operational requirements that make one or the other a best choice in given situations. These details will be dealt with in the design aids.

Another important planning decision that must be made early in the consideration of resource assessment work is,

> Who should do the work of inventory and assessment?

The best answer to this question is,

> The individuals who are citizens of the host country and employees of the responsible government ministry or agency.

This is the best way to ensure that the results of the assessment will be used and have lasting value, and that significant technology and capability transfer will be achieved so that nationals can perform subsequent studies on their own or with limited guidance from foreign experts. It is also the best way for anyone to acquire the essential intimate understanding of the resource -- an understanding too often lacking.

Experience has shown that the way to train and equip a national team of resource analysts and planners is for them to be day-to-day working participants in the initial projects. Comprehensive, preproject training will usually be required, but most important is continuous project work by a team of national counterparts. Training in resource assessment should be a line item in the budget. The practice of tacking on a "training requirement" to the contract performance specifications is not an acceptable substitute.

Information Acquisition and Analysis

Information acquisition and analysis involves filling information gaps through literature searches, interviews, and surveys.

In information acquisition for rangeland development, it is essential to recognize that the central points of interest are the relationships 1) between the vegetation types and their environment, 2) between the plants and the animals that consume them, and 3) between the rangelands and the cultivated lands as regards integration of feed supplies and possible conflicts in land use. The universal problem on practically all rangelands in the developing nations is an imbalance between the requirements of grazing animals and their food supply. This takes the form of yearlong or seasonal lack of quantity as well as a nutritional deficiency of the feed supply. The resource assessment should identify which of, and to what degree, these deficiencies are involved in a given project area. In order to understand the above relationships, it is necessary to have information on a number of parameters discussed in succeeding paragraphs.

The parameters about which information is usually needed can be grouped in three major categories: abiotic environmental factors, cultural factors, and biotic factors. The abiotic environmental factors include topography/landform, soils, climate, and water. The cultural factors include the existing infrastructure and settlements, and current land use. The biotic factors include the vegetation, animals, and humans. All these may be observed, measured, or scored. An integrated resource assessment strives to consider all of these factors and to give them an ecological interpretation that is meaningful in integrated planning.

As one approaches the question of which parameters to measure or observe and the accuracy/precision with which this is done, it is essential to recognize what information is needed to achieve development and management goals. One of the frequent errors in rangeland-resource-assessment projects in developing nations is to make extreme specifications for objective, quantitative measurement of parameters patterned after practices for intensive management in North America. In most cases careful observations and considered judgments about the relative magnitude and directions of change in parameters will provide all the information that can actually be used.

Especially for application in the developing nations, one should carefully integrate the use of remote sensing, systematic aerial reconnaissance, ground observation, and interviews. The guiding principle is to combine these so that the expensive elements of ground measurement and travel are minimized. This is done by optimizing the use of remote sensing and aerial overflight. The goal should be to achieve the lowest cost for ground work consistent with realistic accuracy of data through the use of appropriate remote-sensing technology. This technology may include: more than one point of observation or scale of imagery (e.g., photos taken at various heights) with the larger scales used for sampling rather than complete coverage; and multiple systems, such as satellite imagery supplemented with aerial photography; and imagery taken at different times (e.g., in different seasons).

In selection of ground measurement methods one should recall that most of the vegetational methods and techniques have been designed from research applications requiring high precision and accuracy for relatively small areas. Cost per unit of land was not a matter of great concern. Range surveys in developing countries do not require nearly so much detail or precision; costs should be reduced accordingly. This emphasizes the importance of knowing exactly what information is needed and how precise it must be to meet the objectives for which it is to be used.

One of the purposes of assessment is to paint a simplified, comprehensible picture of the landscape. This requires mapping, and maps require legends. In all instances, considerable attention must be given to developing or adapting legend systems and to characterizing the variables that can be mapped. Ideally, uniform legend systems should be used throughout a country or region so that information is directly comparable among surveys. In legend designs, the first and most important principle is that they should provide for different levels or amounts of detail, i.e., be hierarchical in design. The discriminating criteria should be consistent so that successively more detailed surveys are compatible with the initial, generalized ones. A number of functional hierarchical legend systems have been developed and widely used around the world. The second principle is, therefore, select from existing legends and adapt to local conditions; do not waste time and confuse the issue by reinventing the wheel.

Evaluation of Abiotic Elements

The elements included under the abiotic environment are so intertwined ecologically that they must be interpreted as parts of the whole ecosystem.

Climate. Climate is basic because of its significance in vegetation and soil development and productivity, and in determining cropping potential. The climate is most easily characterized from records of the World Meteorological Organization and from national records where available. The biggest deficiencies are usually in the length and consistency of the record and the poor distribution of weather stations, particularly in the arid regions. In many cases a capable plant ecologist can supplement the record with useful inferences from the vegetation and soils. Interpretations should emphasize thresholds affecting vegetation growth, animal performance, and sound land-use practices, and the variability to be expected, particularly for rainfall. The characteristics of drought should receive detailed analysis.

Water. The distribution and availability of water is important because of its impact on how animals and humans use the land. Water should be inventoried in terms of surface flow and impoundments, marshes, seeps and springs, and seasonal availability. Location of wells, promising locations of ground water, and estimates of potential yield and quality are also important to planners.

Landform and relief. Mapping and characterization of landform and relief are important because of their influence on soil stability and on land-use and grazing-management decisions. In many instances relationships between specific vegetation and soil types and certain landforms are very close. This knowledge is particularly useful in mapping both soils and vegetation and in making ecological interpretations of vegetational responses to management. As a minimum, macrorelief and landform should be mapped and characterized along with the vegetation. The Australian Lands Systems approach has considerable merit in this connection.

Soils. An integrated ecological assessment is not complete without some level of soils assessment. This is usually, however, the most costly part of the entire resource assessment if it is done according to any of the international classification schemes. As long as mapping intensity and classification detail match the information needs, use of an established classification scheme is usually the best option. It is equally feasible, however, to map vegetation-landform systems and then tabulate the relative proportions and kinds of soil normally associated with each of these systems. A third possibility is to map selected soil characteristics, such as surface texture and stoniness, depth, permeability, and fertility, which are particularly relevant to plant growth, erodibility, and resource use.

Evaluation of the Biotic Elements

The main biotic elements are vegetation, animals (domestic and wild), and human society. The latter is so important and complex that it could be treated as a unique category parallel with the abiotic and biotic factors. However, as an element that interacts with and affects animals and vegetation, it is here included with the biotic elements.

Rangeland areas, including the grazeable woodlands and forests, provide food and habitats for both domestic and wild animals. Depending on the emphasis desired, a rangeland area may be evaluated specifically for its potentials and limitations as a habitat for certain species of wild animals or birds or for sheep, goats, cattle, camels, or horses. When it is possible, evaluate the area for at least the most important animals that do, or realistically could, use the area. In a range project the emphasis would usually be an assessment of domestic livestock and big game animals.

Vegetation. On the vegetation side, the purpose of inventory and assessment is to characterize and map the landscape in terms of the plant communities that occupy certain sites. A site is a unique kind of landscape, a particular combination of macro- and microclimate, landform, soil, and biotic conditions that can be found repeated across larger landscapes. These environmentally unique sites can be grouped together, and described, according to similarities in vegetation, productivity, and usually in responses to the activities of man and animals. The vegetation, especially when it is interpreted in relation to climate, landform, and associated soils, becomes one of the recognizable indices of a site. Because essentially the same factors are operating in the determination of an ecological site as in soil formation, a site as defined above will frequently also be represented by a definable set of soil taxa and types. Sites are mappable units of the landscape having applicability to land-use and resource-improvement-and-management strategies.

The goal of a vegetation inventory is to characterize and map ecosytems and ecological conditions as they vary across the landscape so that similarities and differences in land productivity and potential are more readily understood by planners and managers. The vegetation that is characteristic of each site should be described in terms of community structure and site indicator values. When compiled, these types of data permit interpretation of the vegetation in relation to its utility for grazing or browsing and other land uses, as well as ecological condition. Reference areas should be established so that changes may be assessed during and after the project. All too often species are listed in alphabetical order, or some other ecologically meaningless way. Especially for vegetational values, reference areas should be established so that changes may be assessed during and after the project.

From this kind of ecological characterization of the landscape, it may be concluded that there are many kinds of related vegetational observations and measurements that may be appropriate to make, depending on need and the scale or intensity of examination. These may include the following:

- Plant growth forms, species composition, and plant community structure (vertical layering). In the tropical areas, emphasis should be given to fodder shrubs and small trees that may be important either to some animals, or during some time of the year. Data on these characteristics provide a panorama of the vegetation that can be indicative of the general pattern of use and management, including the animal species that would be suitable.

- Typical seasonal development or growth and maturity patterns in the vegetation -- including significant differences among shrubs, grasses, and forbs. With knowledge of these patterns it is possible to define the critical and optimum periods for animal production and the times when the vegetation will be under stress, and to evolve management approaches.

- Vegetation productivity indices or measurements. These types of data reflect the general quality of the environment, provide an initial estimate of stocking rate, and may suggest the intensity of management that can be economically justified.

- Ecological succession and climax as suggested by indications of stability, advancing succession (vegetational change over time), or deterioration. While conditions and trends in many developing countries may not be easily defined, many other indicators of the health of the vegetation are available. These observations are extremely helpful in identifying problem areas, when special measures may be needed.

Observations or measurements should also include features related to vegetation use by domestic and wild animals and by humans. These include:

- Geographic distribution of grazing intensity or forage use in relation to season or time of year on principal species. These types of data are especially useful for assessing stocking rates, grazing patterns, and animal responses, and for identifying problem areas.

- Amount of residue remaining in relation to ecologically allowable minimums. Rapid decomposition, transport by insects, and other losses may reduce the value of this index in the tropics. Nevertheless, when associated with ground cover it is a measure of conditions influencing rainfall infiltration and evapotranspiration.

- Species that receive heaviest and lightest use, show specific animal preferences, and tolerate grazing, where possible to determine. These types of data must generally be left for intensive studies carried out over several seasons. Still, general survey observations can be useful in highlighting major differences.

- Extent and impact of fire as an ecological or management factor; dominant season and extent of burning. What is wanted here is information that can assist in determining how fire has been used to resolve particular problems and with what effect. This background can provide guidance in formulating improved use of fire.

- Use of vegetation for fuel, species used, and relative amounts or apparent ecological impact of fuel harvest. How to provide needed fuel without environmental damage is a big problem in many dry regions. Knowledge of local practices and effects is necessary in order to design solutions to the problem.

These are most of the basic facts that are desirable or essential to know about the vegetation. Beyond this, in the analysis and assessment phases a qualified range ecologist should be called upon to make interpretations of consistent vegetation-landform-soil relationships, ecological potential, current ecological condition (range condition), successional stability and trends, range and vegetation suitability for different species of animals, impacts of burning and fuel harvest on sustained resource productivity, possible rehabilitation strategies, and land-use suitability.

Domestic and wild animals. Domestic and wild animals, as discussed in chapter 3, vary significantly among and within species as to their food requirements and preferences, their responses to environmental conditions, their management requirements, etc. They also may be strongly competitive under some circumstances. Where several species and breeds occupy an area, as is commonly the case in Africa, reliable information on these populations is necessary in order to develop a program appropriate to the animal resource.

In assessing animal populations it is essential to relate them to their habitats and the area they occupy. Range project boundaries should, when possible, encompass migration movements. The types of data that should be sought specifically on domestic animals include: species, breeds, numbers, and distribution. These are essentially census data that are basic to understanding the magnitude and character of the livestock population; whereas, performance and production elements and indices require information on the structure (age and sex) of the herds or flocks, rates of reproduction, mortality and probable causes, adaptation, offtake percentages, weight and age at time of marketing, observable condition of the animals at various times of the year, and milk yields.

The main items of interest are breeding, weaning, and feeding practices. Additionally, systems of herding, enclosures, and handling techniques that may affect productivity and range-use patterns should be described. Information on some of the items may also be gathered when assessing human resources. Such data bear directly on the possibilities for improvements, so their importance cannot be overstressed.

Surveys of natural resources seldom include information on animal diseases. However, inasmuch as diseases are closely associated with animal nutrition, management, handling, migration, and other factors of the environment, assessment of diseases at the same time would appear to be advantageous. Which diseases to assess should be determined by their current and potential importance, and the practicality of prevention or treatment.

In assessments of wild grazing animals, essentially the same kind of environmental information is needed as for domestic livestock. This applies particularly to climate, vegetation, and water. The main differences are associated with the fact that wild animals are free-ranging rather than fenced or herded. Big game animals, for example, commonly have favored habitats that meet their particular requirements for food, water, and protection from man or predators. The specific habitats may change during the year, and in the tropics often involve migration between dry and wet seasons. Dispersal of wildlife from their home range occurs regularly and has no parallel in domestic stock.

Therefore, range-resource assessments that include wildlife should give additional attention to habitat description, as it might have particular relevance to the animal species occupying the area. Diet preferences and adequate cover need particularly to be taken into account. For example, interspersion of different vegetation types may have little effect on the carrying capacity for domestic stock. For wildlife, however, the increased edges of interspersing types such as grasslands, forest, and bush are likely to strongly influence the carrying capacity due to the shelter provided against weather, insects and predators, and the greater diversity of food.

As with range assessments for domestic stock, good information is needed on the use of forage and its effects on range condition and vegetation trends, and (where possible) on the physical condition of the animals themselves, their rates of reproduction, and mortality. Wild game species may concentrate on some plant species or on certain areas that may be available at times of the year when domestic stock are not present. These differences could have significant consequences and should be taken into account on resource surveys. Observation on the degree of use is especially important at times when the vegetation may be most easily damaged, during parts of the year that are critical in the life cycle of the animals, and when competition among the various species is at its peak. Another consideration is that the food preferences of some species may make them useful for control of certain types of brush.

Wildlife assessment for range projects, besides providing the information essential to understand habitats, must also provide certain data on the animal population in order to make management possible. The kind of information needed includes the following:

- Density, in terms of numbers or biomass, and population trends, where possible. These are good measures of environmental quality and, when combined with measures of the vegetation and the abiotic environments, permit estimates of potential productivity.

- Structure of the population in terms of age and sex. When these are combined with information on birth rates and mortality, mating behavior (e.g., polygamous vs monogamous), and density relative to estimated carrying capacity, accurate projections can be made of the likely population changes. It is also possible to recommend management practices such as selective hunting or protection in order to adjust the population to the desired composition and level for optimizing productivity or fulfilling other objectives such as tourism, or trophy hunting.

- Baseline studies. In many cases, studies that permit measurements of trends, as opposed to actual counts, may be all that is necessary. These may consist of fecal counts, track counts, call counts, etc., or actual number counts in limited but precisely defined areas or places. In each situation what is critical is that the specific counts can be made repeatedly in the same place. In that way baseline studies in effect make possible systematic monitoring of population changes. For this reason the initial assessments should indicate where and what kinds of baseline studies should be made.

- Attitudes of local people. Wildlife management depends upon considerable control of harvesting. This presumes support of local people, and little if any poaching, a big problem in many parts of Africa and other parts of the world. The issue of local support is critical and should be given high priority in any assessment of wildlife development. For this the wildlife specialist should combine forces with the social scientist concerned with evaluating the human resources.

The actual methods for making the assessment are not discussed here, because the methods would vary greatly according to the objectives pursued, the facilities and time available, etc. Instead, the interested reader is referred to Riney's (1982) Study and Management of Large Mammals and, Conant et al. (1983), The Resource Inventory and Baseline Study Methods for Developing Countries, prepared for the U.S. National Park Service.

Human resources. All resource assessment is ultimately concerned with managing ecosystems. In this context the assessment of the people of the rangelands takes on a particular relevance, as they are at the same time the principal actors and the ones acted upon in the rangeland drama. As has been stressed in the preceding chapter, this critical part of the ecosystem has usually received minimal attention in range projects.

The crux of the matter is that meaningful communication and interaction must be established between government officials, project staff, and other relevant entities, and the pastoralists in order that acceptable ways for improving resource management can be identified and applied. It is the responsibility of the assessment phase of the project to collect and synthesize information about the rangeland people and the problems that affect them in order to encourage pastoralist participation. Long-term success will depend on continuing dialogue, mutual understanding, and confidence, along with in-depth studies and project monitoring as discussed in chapter 2.

Central to understanding rangeland people is an appreciation of their "ideal" and their "real" behavior. The ideal relates to their goals and deep-seated attitudes. It can be understood by getting to know them well and through carefully designed questionnaires. Understanding real behavior requires close observation.

Also of very general importance is identification of the perceived needs of the pastoralists. These may not correspond to the needs as might be perceived by outsiders who may have quite different objectives in mind. Further, important perceived needs of the pastoralists might often seem to fall outside the concerns of the project as conceived. For example, concern for health might be high but not be included in a project. Still it is clear that health is an important aspect of the human component of the ecosystem. It is time to give more attention to defining the needs of the people involved and to taking them into account when defining the scope of the project. Only in that way can project success be properly judged against the reality of the people involved.

Definition of the geographical area of a project in terms of the people who may be affected and who are likely to interact is essential. This geographical identification of people who are already somewhat linked simplifies communications and the working out of an acceptable program, and generally increases the degree of concerted effort that can be achieved. Definition of the geographical boundary in these terms also makes it easier to assess the direct effects of the project inside the project areas, and the indirect effects outside the boundaries.

What happens locally will largely be determined by the population of that area. For that reason it is necessary to know the population characteristics that have been shown to be critical in the dynamics of range people. These are identified and discussed briefly below:

- Major ethnic groups and subgroups, and society rankings of these groups. Data on groups and their characteristics can be used to facilitate communications, to understand how production is carried out, and to understand the relationships and interdependencies that are important in the functioning of the society. Through such categorization it is easier to identify and deal with differences in production systems, trading practices, diet, degree of dependence on livestock, and other characteristics that may be associated with the various groupings.

- Major social institutions. Of these the most important is the household or family grouping, which may vary substantially in size, composition, and organization. These variables and others affect the functioning and viability of the unit. Organizational aspects that are particularly important are: Who is the head of the family or household; how is the unit organized for production; and how are decisions made within the general context of household organization. Assessment of labor supply and other factors that affect viability may be identified and evaluated within the context of the household.

- Land tenure. Public community and private ownership may all be important in some parts of Africa. Land may be public but wells and other water developments may belong to the people who developed them. Different categories and levels of control may interfere with new procedures that do not take into account traditional practices. Establishment of group ranches, for example, may require different procedures for decision-making than what was practiced in the past. Granting of land title for private ranches may interfere with customary stock movement. It is therefore necessary to define and evaluate land tenure in its various forms. Further, the apparent deficiencies in land tenure need to be corrected with care and only after a great deal of community deliberation and informal training.

- Property rights and rules of inheritance. These may have a strong bearing on various activities, including production. For example, in some societies cattle may belong to the men while the milk belongs to the women. Any change, such as increased emphasis on beef production, could create conflict unless the consequences were well understood and accepted by all concerned. For this reason it is necessary to know who owns what and who has rights in a given situation.

- Major units of cooperation and control. These units may include a variety of groupings that exercise cooperation and control in a rather broad way. Clan groups, age sets (e.g., elders), voluntary associations, and cooperatives are examples. Practically, they constitute the large units of communication and in various ways link smaller units.

- The legal system and the adjudication process. These are concerned with particular types of public decisions that establish the general norms of behavior. They may vary considerably from place to place. It can be helpful to know how they operate specifically in each project area.

- Generation of support for the social system. This may not be easy to identify, but it can be highly important in trying to secure and maintain support for the work of a project.

- Major social services. On a national level it is easy to find information on what main social services (health, education, marketing, etc.) are available for the country. In a project area, however, specific and more detailed information would usually be needed.

- Distinctive cultural practices. Many practices peculiar to various groups may have a direct bearing on production, behavior, and communication. They may often include practices associated with religion such as sacred days and ceremonies, and dietary preferences and taboos.

In addition to the above, some specific types of information on animal and grazing management must be secured directly from the people. Such information may include: their perceptions of the range resource, values of range plants, the role of fire, and descriptions and explanations of herding, breeding, and weaning practices; grouping of animals by species; routes followed; limitations on, or control of, animal numbers; how animals are exploited -- milked, eaten, sold, etc.; and how and by whom the decisions are made regarding the above. If these practices have changed, why? Information on use of and attitudes toward wildlife should also be gathered.

Two of the major catastrophes that affect rangeland people are drought and epidemic animal diseases. It would be important to know the frequency and severity with which these events occur, what responses are taken (if any) to reduce the impacts, and what else should be done according to the pastoralists.

Information on the above may well influence the orientation of the project and could especially help to identify areas where effective beginnings could be made on improving animal performance and rangeland productivity.

Evaluation of Institutional Frameworks

Effective execution and continuity of the project are highly dependent on an institutional framework that can support those activities. Project objectives, design, and scope therefore need to take institutional capacity and requirements into account. Indeed, major emphasis may need to be on building the necessary institutional framework, before significant field activities can be undertaken.

In the assessment of institutions relative to rangeland development, the critical objective is to determine how adequate the present structure is for conducting range activities and to identify specific deficiencies and needs so that these may be taken into account in project planning. Four major aspects that usually need to be assessed are:

Policy and regulations. Very often governments do not have clear policies that commit them to a definite and continuous course of action relative to rangelands. Similarly, regulations may not be adequate to permit an effective program. It is therefore essential to document relevant current policies and regulations, including those having to do with such related matters as forestry, soil conservation, animal husbandry, land tenure, and water development.

Organizational structure and functions. Various agencies may have partial responsibility for certain aspects related to rangelands. Not unusually, for example, these include agencies for water development, forestry, general rural development, and others. When each agency treats a part of the range ecosystem, their efficiency is likely to be limited because financial and human resources are rarely adequate for such splintering of functions. It is essential to identify not only the organizational units responsible for the various ecosystem components, but also the ways in which coordination is sought, and its effectiveness. Relationships with planning units should be clearly defined, as should staffing and budget. Functional relationships between government agencies and relevant groupings or organizations of pastoral people, and with local government units, should be described. In short, institutional assessment should provide the information needed to indicate the ways in which current organization needs to be changed or strengthened, and to provide a basis for setting up a range agency with authority appropriate to its responsibilities.

Research and extension. Types of research that have been done or are being carried out should be described in broad terms for agriculture in general. Range research and research in closely related fields should be detailed to permit evaluations as to relevance and adequacy. Additionally, information on research facilities and available staff is needed to facilitate estimating the opportunities for expanding range studies. Organizational details affecting formulation and execution of research programs should be described.

Assessment of the extension services may be along similar lines. Additionally, adequacy of research information and linkages to extension should be assessed and constraints in transmission and application of information to potential users identified. Particular attention should be given to defining areas of active participation of the pastoral people in extension activities and to evidence of various extension practices, including demonstrations. The relationships and effects of credit, markets, transportation, communication, and other factors affecting extension programs should be identified and decribed wherever possible.

Education and training. Any range program requires staff educated and trained to carry out a diversity of tasks. The assessment phase therefore should describe existing facilities and programs that could contribute to the preparation of people to work in range programs and the level and magnitude of the contribution. Quality of education and training should receive close attention. With these types of data, reasonable judgments can be made about improving effectiveness.

Evaluation of Infrastructure -- Institutional Elements

Evaluation of resource use, development, and management is also needed, and should cover traditional and nontraditional land use. Land-use studies should consider particularly those uses and developments that have a direct bearing on rangelands. These include settlement, agricultural cropping, infrastructure for transportation, livestock finishing, and marketing and trade. Other uses include potential cropland areas; wood, charcoal, and other plant materials; minerals and energy; archeological sites; and tourism and recreation. The assessment must cover the majority of these items before it will be adequate to support integrated resource planning.

It is also important to know the views of tribal and other important groups, and of the government regarding grazing-land tenure and the use of forage and water in rangeland areas. Existing or potential conflicts between tribal interests and government interests are also important to know about. The organization of government ministries for controlling and guiding the development and management of rangelands needs to be documented. The assessment project should investigate all these areas so that related needs can be addressed in the development plan.

Planning the Project

Project planning involves the analytical selection of alternative actions that will remove the causes of identified problems and achieve the goals and objectives set down in the resource-assessment-preplanning phase. The selected actions are then scheduled in a smooth-flowing sequence and the logistics and operational details of the project worked out. It is assumed at the outset that the assessments developed in the information-acquisition-and-analysis phase will have provided all the necessary facts and interpretations for planning. If the resource-assessment-planning details were well handled, the data will have been specifically related to anticipated questions and decisions. The planning process will nearly always, however, identify new information needs or additional analyses and interpretations that are crucial to rational decisions about project alternatives. This obviously involves a loop back to the information-acquisition-and-analysis activities, which is the primary reason why continuity of personnel between assessment and project planning is essential.

Implementing the Project

If the analytical and decision processes were rigorously carried out, attainment of goals and objectives in a project should be possible. However, planning and implementation are seldom, if ever, perfect, and adjustments in plan or fine-tuning of certain actions are practically always needed. This need plus the interrelationships among different projects in a total development plan and the likelihood of unanticipated side effects of project actions make continuous assessment of the resource, of human factors, and of the implementation results imperative. Thus, the final function in the development-planning-and-implementation process -- monitoring -- actually starts during the implementation phase.

Monitoring and Follow-through

Monitoring brings the data-acquisition-and-analysis functions back into play but with a different thrust. Here the projected accomplishment schedules, action-result relationships, resources, people, animals, economy, infrastructure, and costs are individually and collectively monitored to determine: if the changes that take place are moving toward worthwhile goals at acceptable rates, if any unanticipated and adverse side effects are resulting from the action program, and if a smooth transition is taking place into the next phase of the development or management program. These determinations may involve gathering data on vegetation composition, productivity, vigor, and residue after grazing; on animal performance, gains, progeny, condition, and offtake; and on soil conditions related to stability and erosion. In order to do the monitoring effectively for many of these items, reference areas should have been established early in the course of the project.

In the follow-through phase, appropriate action is taken on these findings to redirect or fine-tune the implementation for greater achievement.

Ensuring Use of Assessment Results

One of the major concerns of donors is that many resource-assessment projects have not been used to the extent anticipated, sometimes not at all. Following are some measures that can be taken to ensure successful use of assessment information:

- Provide for adequate training and involvement of nationals in the assessment project; budget, at the outset, for their continuation through the full development project.

- Provide for one or more of the foreign experts involved in the assessment to continue with the project. This will facilitate information flowing between the resource assessment and the planning and implementation of development projects.

- Ensure that the resource-assessment staff monitor planning needs and are available to prepare supplemental interpretations to meet unanticipated information needs.

- Perform the monitoring assessments, including social benefits, starting with implementation and continuing throughout the life of the development project so that problems can be anticipated and adjustments can be quickly made.

If donor-agency staff and contract planners give careful attention to the generalized guidelines presented in this chapter, they should find that all rangeland-resource-assessment work will be economically and effectively performed. And most important, use of the data in the subsequent development-and-management-planning work will be assured.

Finally, the mark of a good planning job is adaptation to the conditions and informational requirements of each individual project.

This chapter should be read in conjunction with chapter 6 on integrated land-use planning because, in practice, the two functions are inextricably linked together.

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Chapter 6

Planning for Integrated Management of Rangeland Resources

This chapter reviews the planning process and the terminologies that different agencies (especially USAID) apply to rangeland planning. Planning involves a continuing sequence of interrelated tasks including goal and problem identification, ordering and scheduling of activities, personnel, administration, budgeting, and fiscal control. Here these tasks are related to the integration of range-resource uses. When a project is approved, these tasks are performed, through the implementation, monitoring, and follow-through steps. The planning process remains much the same in concept, no matter which agency's terms are used.

Integrated Resource Use: Concept Definition

Integrated resource use is the coordinated development and use of natural resource areas for the sustained benefit of society. It encompasses more than an environmental impact assessment of the natural-resource base. The natural-resource component is just one of four basic elements of rangeland systems. Other elements represent the political, economic, and social aspects of the region to be developed.

Integrated resource use implies that each land area must be developed and managed to benefit people in ways that are compatible with its ecological potentials and limitations. Animal, human, soil, vegetation, water, and mineral resources and their interactions must all be considered during all phases of the planning process. Development using this concept involves enhancing the suitable land uses or developing economically viable new uses to meet the people's long-term needs on a sustained basis.

Integration of these uses into a harmonious system of production can be achieved only by planning that is motivated by sustainable goals, recognizing that an acceptable solution often involves striking a balance between short-term and long-term benefits. Integrated resource use is difficult to implement, even in developed industrial nations, given the social pressures and politics of land-use planning and of resource development and management.

Integrated Resource Use in Developing Nations

Integrated resource use implies a planning sophistication that may be extremely difficult to implement on a sustainable basis in developing nations. The major limiting factors are the lack of a trained, experienced, professional staff, and the lack of a political environment and organizational framework that allows stability of purpose and direction. Integrated resource use remains a worthwhile goal as development programs continue to train and assist developing countries to build the necessary infrastructure to coordinate this complex level of planning and management. Moris (1981) suggested that simple, easy to enforce, single-use production systems might be preferred over multiple-use systems, until the degree of control of these production systems can be assessed in developing countries. Indeed, single-use management can be an appropriate strategy when it results from an integrated-resource-planning process.

Modeling and Development Planning

Though models are often associated with computers, they can also be conceptual, physical, mathematical, or even a set of words. Models have been useful in management, research, and planning. They have assisted in obtaining a better understanding of the interrelationships between the components of a system and in evaluating economic, ecological, political, and social relationships. These relationships can then be used to project current trends into the future and to evaluate development strategies.

One of the dangers of using models in the planning process is that often those designing and using the model become so involved with the model and its development that they mistake it for the real system being modeled. Thus the model becomes an end rather than a means to an end. Even though models have made many significant contributions in many areas, they must be recognized as simplifications of real-world systems; as such they do not account for all of the complexities and interrelationships of the systems.

Most developing countries have a pool of people who have had or are obtaining experience with computers and modeling techniques while in training programs. These people usually have a great deal of enthusiasm and want to use the techniques and equipment on which they were trained back in their country. Computers, especially microcomputers, are becoming available in many developing countries in rapidly increasing numbers. Even though benefits can come from this, caution should be exercised in all phases of development activities to ensure that appropriate methods are used and that these tools are not extended beyond their appropriate limits.

Integrated Resource Planning

Integrated resource planning as used in this book can best be defined by examining the words themselves. The individual terms "integrated," "resource," and "planning" are used in many different ways. The term "resource" is used here in a very broad sense to include all the natural, social, economic, and political attributes available to a given region or area that can be used or interacted with by some management strategy. Interactions may be either direct or indirect.

The term "planning" refers to the process by which development agencies and governments select, manage, and evaluate projects directed at improving the potential and management of the "resource" base. The general steps of this process are presented later in this chapter, along with the specific steps used by selected development agencies.

The term "integrated" is used to imply that many aspects of the "resources" will be considered during the "planning" process. It also points to the need to use a multidisciplinary, team approach during all phases of the process.

In the broadest possible sense, integrated resource planning involves: 1) the conceptualization and confirmation of problems and needs, and 2) the analytical design of programs and projects to address these problems and needs. Planning attempts to chart a logical, orderly sequence of actions for:

- Identifying goals and beneficiaries
- Achieving worthwhile goals
- Solving problems

- Ensuring maximum effectiveness in the use of natural resources, capital, labor and human skills, and scientific and technological knowledge

It is the approach used in planning, rather than what uses are involved, that typifies "planning for integrated management." Planners and developers must realize that sustainable resource-use strategies are the result of: 1) complete information acquisition and analysis, 2) thorough problem analysis, 3) unbiased determination of potential alternatives, 4) careful evaluation and selection of alternatives leading to the betterment of both the resource and the people dependent upon it, and 5) continuous monitoring and evaluation of development programs to adequately document successes and failures so we can learn from past efforts.

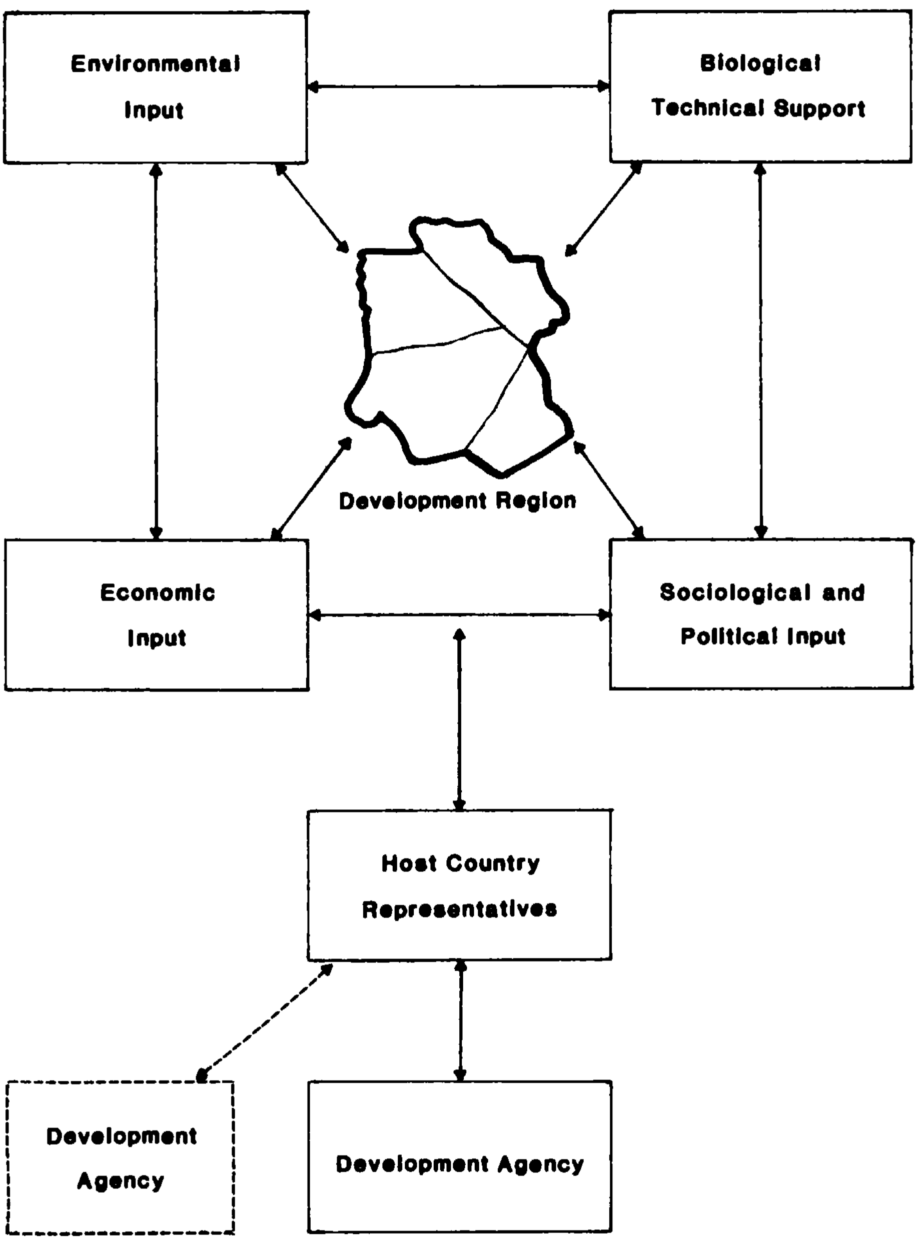


Figure 14. Representation of integrated resource planning utilizing multiple disciplines, involvement of host country representatives, and involved communication throughout.

Planning to develop and guide programs in developing countries should involve a level of integrated resource planning at some point. The diagram in figure 14 illustrates such a process involving a variety of disciplines and host country representatives in the development process. The multidirectional communication patterns illustrated are essential throughout to ensure attainment of long-term development goals. Integrated resource planning is done: 1) to develop a broader perspective of the situation, 2) to conceptualize integrated programs for development, 3) to evaluate interrelationships and conflicts between resource uses, and 4) to set priorities and directions for the separate elements in the development plan. In contrast, figure 15 illustrates a unidirectional, single-sector development process that is conceived and implemented somewhat in isolation.

With good integrated planning conducted at the national level, the process of planning for specific activities can sometimes be done in the context of single disciplines for each of the separate elements, components, or projects in a development plan. However, if this single-element procedure is used, there is great danger that those closely involved may lose sight of goals and interrelationships. In addition, there is the possibility that new

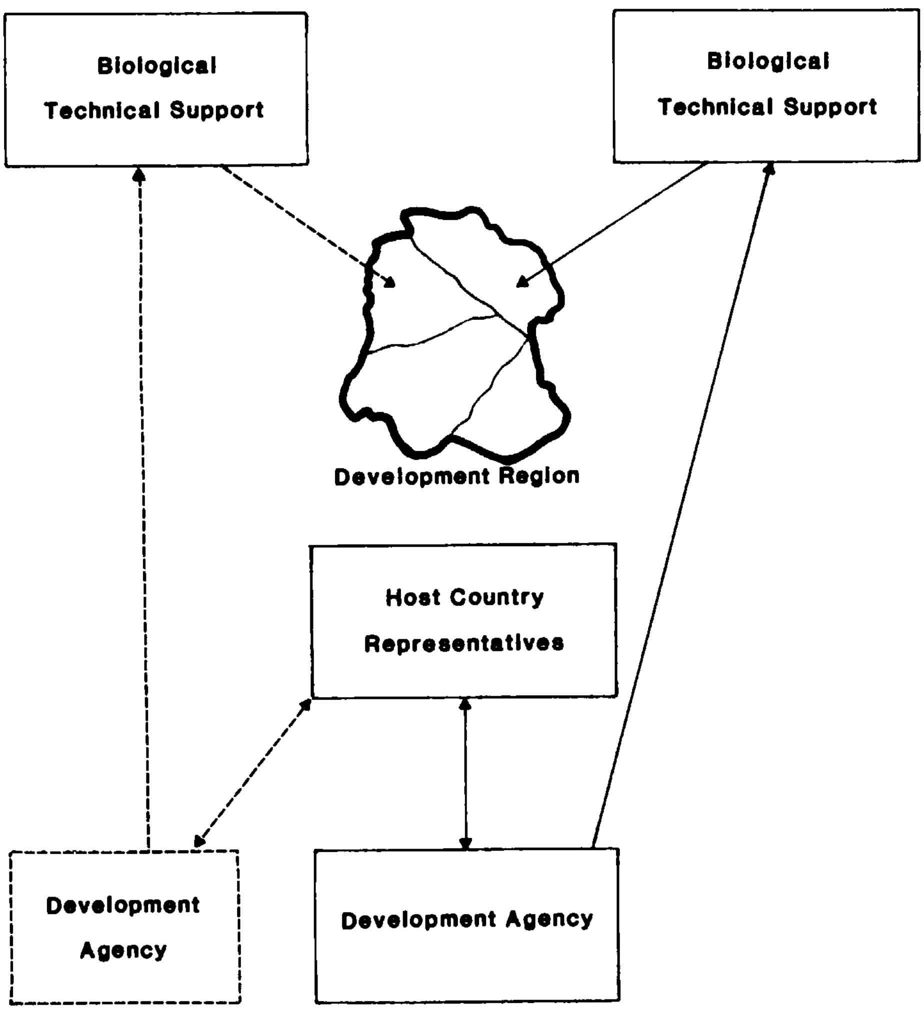


Figure 15. *Representation of a one-directional, single-sector development process with activities being conducted somewhat in isolation from each other.*

interrelationships, impacts, and concerns may surface from actions proposed using the integrated planning process, which ordinarily would not be discovered until the implementation phase if a single-discipline planning process were used.

Planning as a Step in the Development Process

Fundamentals

After objectives are set, planning is made up of reiterative sequences of assessment, problem analysis, and rational decision-making. Problem analysis is the process of discriminating between problems and symptoms, identifying the fundamental causes of problems, and proposing solutions that will remove the causes and thus solve the problems. Analytical and subjective thinking together with rational decision-making are inherent, reiterative functions in problem analysis. Taken together, the principles of problem analysis and rational decision-making are the cornerstones of planning. Problem analysis is therefore a process of:

- Specification of problems and identification of causes
- Analysis/assessment of causes
- Specification of alternative solutions
- Assessment of side effects of alternatives

Decision-making/Selection of Alternatives

This process results in a plan when the selected alternatives are translated into specifications for implementation and when each specified action element is scheduled in a workable sequence.

Problem Analysis + Specification + Schedule = Plan

The planning function is made up of a reiterative series of the following major steps:

1. Information accumulation, reduction, and analysis
2. Goal and objective setting
3. Problem analysis and rational decision-making
4. Alternative selection and scheduling

The central focus of planning is to specify the essential steps and to set the guideposts for a course of action.

Applying the above principles, the universal steps in planning are carried out as outlined in table 5. These steps can be carried out for many purposes and at many levels in the context of technical assistance and integrated planning for development and resource management.

Table 5. Major Steps in the Planning Process

I.	Preplanning		
		Situation Assessment	
		Goal/Objective Setting	
		Problem Identification[a]	
II.	Planning for Program		
		Information Summarization and Evaluation	
		Problem Identification	
			Analysis
			Decision-making and Selection of Alternative Actions
		Working Strategy and Logistics	
		Ordering and Scheduling Action Elements	
			Facilitating Actions
			Direct Actions
		Personnel Requirements	
		Logistics	
		Administration and Management	
		Budgeting and Fiscal Control	
III.	Plan Implementation		
		Action Elements Per Schedule	
		Project Coordination	
		Monitoring and Fine-tuning Action Plan	
IV.	Follow-through		

[a]The techniques of problem analysis are reiteratively applied throughout all functions to specify or fine-tune action needs.

When considering the concepts of problem analysis and planning as organized in table 5, it is important to be aware of the following points:

- While these steps are not mutually exclusive and may be developed simultaneously, planners normally work through the steps in table 5 from top to bottom.

- Some steps may be partially developed and laid aside, particularly among the secondary functions under "planning for action program." The most efficient way to proceed is often to carry certain functions as far as available information will allow, to go on to the next function, and then to loop back to revise, update, and complete the work. Obviously, certain functions are prerequisites and must be completed before the next phase can begin.

- Cycling back through the process plays an essential role in the complete process. As one moves down the activity sequence (table 5), new information or newly perceived problems will require the planners to cycle back and refine or completely revise the work from an earlier function before proceeding. This often makes the difference between successful projects and those with serious implementation problems.

- All steps must be completed to ensure project implementation that maximizes benefits, including technology transfer, to the recipient country and its people.

- Involvement of local government personnel, contractors, and key personnel from the target area is crucial throughout the major project stages.

- The practice of changing contractors, especially in the planning to implementation and(or) follow-through stages, reduces program effectiveness and the savings that competitive bidding is expected to achieve. Hence, donors must select qualified contractors and assign the complete program to them.

Social-impact Assessment

Social-impact assessment follows the major steps listed in table 5, but uses somewhat different terms and asks the planning questions that emphasize people. These questions are illustrated as follows:

- Scope: How big is the problem?
- Problem definition: What is causing the problem?
- Alternative formulation: What are the alternatives?
- Profiling: Who is affected?
- Projection: What are the impact trends?
- Assessment: What difference does the impact make?
- Evaluation: What is the acceptance?
- Mitigation: How can adverse impacts be avoided?
- Monitoring: How good were the original guesses?
- Management: Who has continued responsibility?

The above questions facilitate the determination of who benefits and who loses what in proposed development projects.

The Planning Process in Operation

The planning processes used by different development agencies are similar but use different terms. Figure 16 compares the descriptions of the general planning processes of selected agencies. The concepts presented in this book can be used within all of these processes. More attention given to sustainable resource management in each agency's planning process will provide more effective long-term solutions to the problems facing developing countries.

Planning Sequence

The relationship of integrated resource use to development planning can be more adequately understood when placed within an outline of the specific sequence of planning activities that are essential to resource development and management. The following outline is appropriate to countries that are just embarking on a program to increase the efficiency of resource use, strengthen their economic position, and provide their

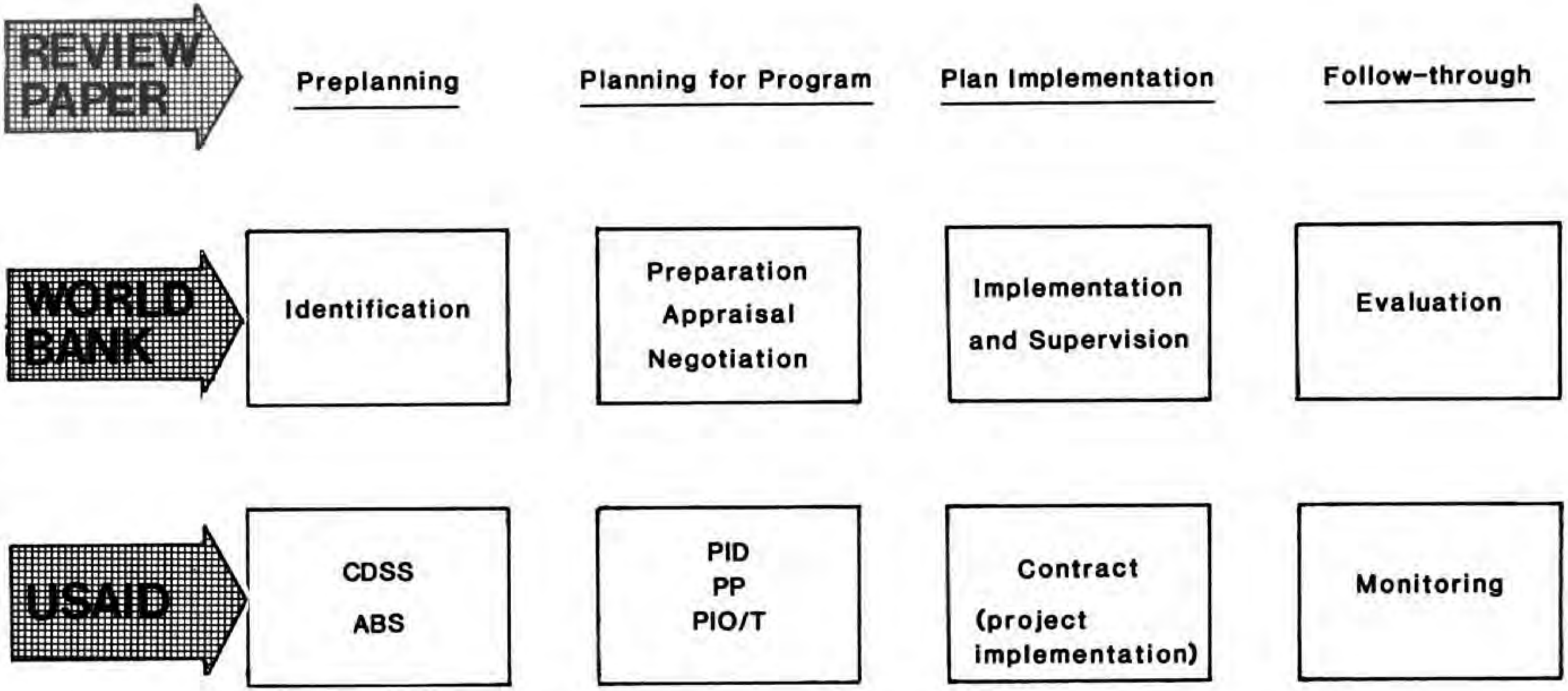


Figure 16. *Generic terms for the major steps in the planning process as developed in this paper and equivalent terms used by the World Bank and USAID.*

people with an improved standard of living:

1. Broad, overall, or comprehensive planning
   a. Organization-building and institution-building
   b. Legislation, policy, long-term goals and objectives, and program priority and direction establishment
   c. National- and regional-level development
   d. Resource allocation through integrated planning

2. Area-specific planning
   a. Integrated local area development
   b. Resource area management

The likelihood of success is greatest if planning and development programs follow this sequence. For example, 1) if training is not a part of institution-building, the country will not be able to participate in development or to maintain the gains once a development/management project is completed by a donor nation; 2) if organization-building within the host government is not guided to meet minimum administrative and management needs, a national bureaucracy will result that totally absorbs newly trained human resources; 3) if institution-building is not accomplished early on, there will be no local, organizational framework to accommodate new capabilities and development work will lack a focus that meets country needs; and 4) if some progress is not made in resource allocation at the national and regional levels before moving into projects in area-specific planning, truly integrated resource development will not be achievable -- the results will merely be forgotten "band-aid" projects.

Most rangeland-resource-management projects will involve planning in local resource areas, but if such detailed planning has not been preceded by planning and action at the national or regional levels, the effectiveness of the plans may be restricted, and adverse side effects among land uses might surface after they have created secondary problems with irreversible consequences.

Planning Process Used by USAID

USAID uses a six-phase project-planning procedure (figure 17). In recent years they have emphasized planning strategies that sustain resource productivity and improve the quality of life for the dependent peoples. This emphasis is intended to focus adequate attention on the environmental concerns, which in turn increase productivity, stabilize the resource, and increase benefits.

USAID's experience suggests that, if adequate data are available and good judgment is used in going through the six planning steps, the chances for a successful, environmentally sound project can be improved. Each step provides an opportunity to examine baseline inventory data and assess the environment. More emphasis must be placed on problem analysis to identify inadequacies in resource use, management, and production, and to provide focal points for programs. Thorough, reiterative problem analysis throughout the planning process helps to detect ill-advised or potentially unfruitful project directions.

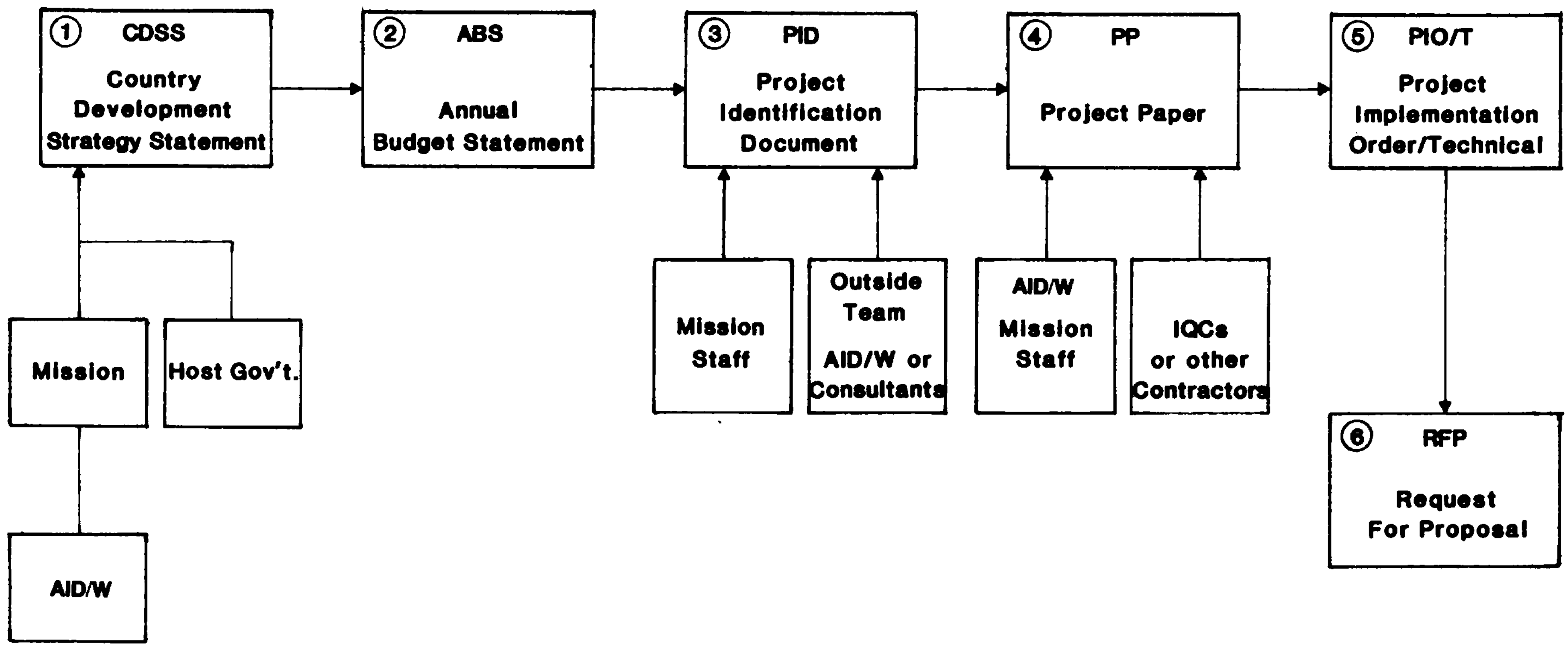


Figure 17. The USAID Planning Process.

Project Monitoring and Evaluation

Due to the complexity of implementing projects, it is impossible to anticipate all problems that are likely to arise. Thus, project monitoring is required to provide continuous feedback on progress and to identify unanticipated problems that may require redirection or fine-tuning of the program. Hence, flexibility in project performance must be incorporated into the design. The experienced contractor is aware of this and his pre-bid planning goes as far as possible to accommodate uncertainty. However, from the donor institution's point of view, contracts are easier to monitor, and compliance simpler to determine, if the performance document is rigid and tightly specified.

Monitoring responsibilities fall into two categories: 1) those of the donor and local institutions, and 2) those that reside with the contractor. Once a performance agreement is reached, the contractor's responsibilities are specified. These responsibilities are concerned with project operations, administrative management, fiscal control, logistics, personnel, quality control, and performance-schedule compliance on deliverable tasks.

Even when all parties have done the best possible job in planning, negotiating with the host government, and reaching an agreement on the performance contract, unexpected events typically occur. These problems can require revision of deliverables, project redirection, and in some instances even present the option to close out the project. Such situations can arise through no fault of the host country, donor institution, or contractor, although their causes can usually be traced to inadequate analysis of the working situation, poor problem analysis, or simply poor planning in the early stages of project development. By its very nature, development is a complex process fraught with uncertainties. Recognizing this, host countries, donors, and contractors must be willing to adjust project implementation to new realities.

The responsibilities of donors, host-country institutions, and contractors in project monitoring and guidance might be summarized as follows:

- Donor institutions, host-country institutions, and contractors are responsible for monitoring project performance and communicating their findings to one another regularly.

- Contract flexibility is needed to allow reasonable reorientation of project direction or occasional renegotiation of project deliverables (when causal factors were unanticipated and beyond the control of the contractor) and, in extreme instances, to provide for project cancellation or reassignment of the contract to another contractor.

Duration of Projects

Ecological and social components of rangeland production systems are very complex and dynamic. These systems are slowly but surely changing as they interact with system components and respond to the climatic variations that typify rangelands. It is generally agreed that because of these characteristics and our general lack of understanding of them, projects need to be long term (10 to 20 years). Changes in the existing production systems often occur slowly, and projects that end after 3 to 5 years tend to confound the development process. Numerous examples have been documented that show the up-and-down nature of short-term projects. Such projects seem to be successful after 3 to 5 years, but when external support is withdrawn, they die.

The cyclic nature of droughts and other stresses endemic to rangeland areas should be considered as management systems are developed and tested. Some exotic livestock breeds and plant species have been introduced by projects that ended before the stresses of drought or disease were experienced. These introductions have failed at times, leaving the local managers frustrated and perhaps less willing to adopt new practices in the future. It has been observed that even the sahiwal cattle numbers were dramatically reduced by the 1984 drought in Kenya, while the East African zebu and the Boran breed suffered less severe losses.

Post-project Follow-through

Renewable-resource-development projects are significantly different from infrastructure projects such as the building of a school, a dispensary, a road, or a bridge -- once done they are forgotten. This thinking on the finality of individual projects is not tenable in the natural-resource-management area. Resource management is a continuous process. Conditions change, and redirection and follow-through activities are absolutely essential to ensure full benefits from expenditures on earlier projects. In effect, a project often creates a need for another project or for a gradual phase-out, rather than abrupt termination. It is essential that a follow-through-and-monitoring period be planned from the outset. The follow-through often requires a continuing, high level of financing in the initial post-project years to enable host-country personnel to carry on and to realize full benefit from the initial project.

Development-agency programs and staff performance should be evaluated in terms of post-project benefit to the host country, not just the number of projects conceived and completed. Project conceptualization, and every subsequent step, must anticipate and provide for necessary follow-through so that benefit to the host country is realized. Plans for gradual phasing-out of external project support should be included throughout the planning process. In many cases, projects costing many millions of dollars have not been nearly as effective as they could have been because of a failure to provide a phase-out or transition period that allowed the host government to assume the entire project responsibility.

Planned post-project follow-through should be carried to the point of analyzing and determining what kind and level will be needed. This activity should be budgeted in the initial project planning. Follow-through is an activity that also needs to be monitored because, as a project progresses, the needs for follow-through can change from what was initially conceived. For example, initial training of counterparts may not materialize as anticipated, thus leaving no one to carry on who understands the project. Alternatively, the project may go well and counterparts may be trained to take over, but the government may not have the resources to pay them to continue into the follow-through phase. Each situation will require that the donor develop a specifically tailored follow-through response.

General Observations from Experience

Integrated resource planning provides many lessons that should be applied to future development activities. Donor agencies are increasingly aware of several factors that should be considered as development programs and projects are planned and carried out. Some of these follow:

- Many donor agencies or contractors do not employ headquarters staff within each required technical discipline, including range management. They seldom have the array of qualified technical people on field staffs -- except for the consultants on projects or on short-term assignments. Frequently the field-level decisions concerning the renewable natural resources with rangelands are made by animal-production specialists or people more distantly removed from rangelands.

- Unfortunately, consultants hired to advise during the early planning stages -- though technically competent -- are sometimes not experienced in the developing-country setting. As a result, they have difficulty making modifications to textbook approaches that are necessary to reflect local needs. Without qualified staff, donor institutions cannot identify inherent problems in these plans and so often end up with projects that have the wrong focus or that apply inappropriate technologies.

- In many donor agencies, the present planning process is strongly oriented to the annual budget and program projections, i.e., the bureaucratic and legislative process of procuring and continuing funding to the agency. Many of these existing procedures work well where the project is the construction of turnkey facilities (roads, etc.), a consultancy that generates workshops and training programs, or baseline reports. A longer horizon is needed where long-term programs in natural resources development and management are concerned. Donors need to appreciate that nearly all worthwhile programs in resource management are of necessity long term. Current donor efforts to provide longer-term phased funding for 10 to 15 years are an improvement.

- Generally speaking, well-planned and effectively implemented resource-management-and-development projects have been environmentally sound. If such a project is not environmentally sound, then it is not a good resource-development-and-management project either.

- The early planning processes in many donor agencies do not include an adequate problem-analysis procedure that specifies and prioritizes country problems, identifies the causes of those problems, and provides an adequate sequencing of events to alleviate the problems. The planning process rarely seems to identify and implement facilitating actions that often must precede or be interwoven with project implementation to ensure its success.

- Most developing countries have many donors interested in offering some kind of assistance. There exists a natural incentive for all recipients to seek to maximize the amount of development funds flowing into the country. This makes the process by which donor agencies carry out the problem-analysis phase of their planning even more important. In particular, donors must collaborate with developing-country governments to establish priorities and complementary projects.

- Keep trying! The process works but is at times frustrating. Progress is not easily seen without stepping back to gain the broader perspective.

Annotated Bibliography

Organization of American States (OAS). 1984. Integrated Regional Development Planning: Guidelines and Case Studies from OAS Experience. Dept. of Regional Development, Washington, D.C. 230 pp.

This book documents experience in regional-development planning and investment-project formulation, and includes the incorporation of environmental considerations into this process. It was prepared in cooperation with the National Park Service-USDI and the U.S. Agency for International Development. It includes six excellent case studies of regional development from Latin America. Available in English and Spanish.

Ehrhardt, R., A. Hansen, C. Sanger, and B. Wood. 1981. Canadian Aid and the Environment. A joint study by the Institute for Resource and Environmental Studies (IRES), Dalhousie University, and the North-South Institute. IRES, Halifax, Nova Scotia. 94 pp.

Canada's current and potential role in international development as it relates to the environment is discussed. Seven projects are reviewed with information on how the environmental concerns are interwoven with them.

Chapter 7

Rangeland Management and Improvement

Chapter 7 wraps up this review with the concepts that underlie rangeland management. The emphasis is not on the mechanics of management. Rather, several of the principles for rangeland development, such as control of undesirable plants, seeding, water development, and distributional control of animals, give fundamental information that can be expanded into full specifications for rangeland management structures and animal grazing procedures. Practical ways to increase forage production, while at the same time conserving rangeland resources, are discussed.

Grazing -- A Management Tool

By necessity, the priority use of rangelands in the developing countries will be for food production, primarily animal protein. Management of these rangelands must, therefore, put major emphasis on improved livestock and game productivity. At the same time, due to the need to optimize overall returns from natural resources, multiple use should be practiced wherever possible. For instance, in many developing countries tourism is a significant source of highly needed foreign exchange that is at least partly dependent upon rangeland resources. Above all, today's production must not be gained at the expense of tomorrow's resources.

A compelling reason for conserving the range environment is that the values received from rangelands are often not high enough to justify the large investments required to correct land damage caused by past mistakes. However, improved range management is not likely to occur unless it results in benefits for the resource user, including greater animal productivity and enhanced plant cover that protects the soil. This chapter discusses management of the rangeland complex of animals, vegetation, and soil for sustained and improved productivity. It deals with some aspects of animal management and production, but the principal purpose is to discuss practical ways to increase forage production and to achieve range conservation and improvement.

Although some of the more common grazing systems are briefly discussed, major importance is placed on observation, judgment, and recognition of the need for flexibility in management. In other words, emphasis is placed on the basic principles from which management draws, rather than on the mechanics of management.

As demonstrated in chapters 1, 2, and 3, range ecosystems vary greatly in terms of their environmental, plant, animal, and human components. All, however, encompass one central process -- the conversion of solar energy into plant energy, and then into animal products useful to people. The task of management is to optimize that energy flow to fulfill human needs in a way that is sustainable. The process or activity that largely determines the energy flow from plants to animals is grazing, including browsing. For this reason, grazing management is mostly concerned with controlling that which goes on at the interface between plants and animals, where the amount and quality of forage intake by the animals and the amount of photosynthetic tissue left to the plants are determined. Grazing, then, is of major significance to both plants and animals, and ultimately to the functioning of rangeland ecosystems.

Another important feature of grazing is that it is manageable. Of course, there are difficulties and constraints in grazing management. Range management aims at overcoming those constraints. For example, herding requires dedication, understanding, and coordination with climatic as well as with other factors. Control through fencing may reduce herding, as in developed countries, but it is expensive and impractical where many large, wild animals occur. Also fences may not fit well with traditional practices.

Figure 18. *Wool sheep grazing improved montane forests in the Kenya Highlands.*

Irrespective of the grazing controls used, the characteristics of the range vegetation must be taken into account. If range vegetation were constant in space and time, there would be virtually no problem of management except deciding what kinds of animals and how many. But because range vegetation varies from site to site and is always changing in terms of quantity and quality, management must change accordingly. A key to successful range improvement is to take advantage of favorable climatic conditions to reduce the impact of droughts and dry seasons in a way that will improve rangeland condition.

Vegetation Characteristics and Grazing Management

The main variables that need to be taken into account in designing a grazing strategy for range vegetation are plant and animal species, growth period, dormancy, and site variations.

Principal Species

Biomass availability and palatability determine what forage species an animal grazes. Availability is influenced by growing season and grazing pressure or degree of forage use. Preference for particular plant species, individual plants, and parts of plants varies among individual animals, animal species, and time of year. Some plant species are highly tolerant of grazing; others are susceptible to injury. Some plants are palatable; others are not. Some plants stay green and palatable longer than others and are preferred over a long period of time each year. These considerations, coupled with changing nutritive values, make it necessary to know what species the animals are eating throughout the year.

Active Growth Period

Two characteristics associated with the period of active growth have close connections to grazing: 1) The high nutritive quality of the forage species favors animal growth and 2) removal of active photosynthetic tissue during the growth period may severely reduce plant vigor and productivity.

Although notably influenced by rainfall amount and distribution, the active growth period also depends upon species and soil-moisture storage, which is related to depth and texture of soil. Annuals in particular usually respond to adequate moisture only during one rainy period, and may go dormant before soil moisture is exhausted. Some plants, such as shrubs and certain legumes, may stay green well into the dry season due to deep root systems or other characteristics. Because the active growth period is highly rainfall-dependent in arid and semiarid regions, it is also variable in timing, duration, and biomass yield. The dependence on rainfall permits short-term forecasting of forage conditions.

Differential grazing among species during growth is an important element in changing competitive relationships and floristic composition of the vegetation. Upright palatable species will be the first to be weakened or killed by overuse. Prostrate and unpalatable species will then be favored and will prosper. Grazing management, therefore, is faced with an apparent contradiction of needing to use the available forage during the time of optimum quality, and at the same time avoid such heavy grazing as to reduce productivity or change the vegetative composition in unfavorable ways. The way out of the dilemma is to save enough forage for dry-season grazing. In that way, forage use during the growing season will not be excessive. Danger of overuse during the growing season is, of course, much less with annuals than with perennials. Prostrate species such as African star grass are not easily overgrazed due to their growth form.

It should also be noted that digestibility and protein levels of the grasses are highest in the earlier stages of growth and decrease rather sharply as flower-stalk formation begins. Early and heavy grazing causes the most reduction in yield relating to the amount of forage consumed. Decrease in quality with advancing maturity is less in vegetation grown under arid and semiarid conditions than in humid areas. This loss in quality is accentuated in humid areas due to low soil fertility and large grasses with a high proportion of crude fiber. Grasses of any region with high rainfall may have low dry-matter content during that time. These relationships help to explain why animals on arid and semiarid grazing lands may, despite the relative sparseness of the vegetation, out-perform animals on lush lands in the humid tropics.

Period of Dormancy

In general, grazing of grasses during the part of the year when plants are dormant has much less effect on the vegetation than does grazing in the growing season. However, indirect effects can result if excessive grazing results in physical injury to the plants, excessive drying, and soil erosion. Plants in which photosynthesis is still occurring can suffer grazing injury, as can shrubs that are heavily browsed.

The degree to which the various plants go into dormancy depends upon the genetic characteristics of the species and the duration of the dry season. In regions where rainfall is less than 700 mm, livestock can generally be maintained in reasonable condition on grass alone through the less-than-6-month dry seasons, providing sufficient dry matter is available. Maintenance without serious weight loss during the dry season is not possible in the humid/dry tropics under conditions of low soil fertility such as the llanos of Colombia and Venezuela. If palatable shrubs, trees, or legumes are present, forage from them will be rich in proteins that will supplement the poor-quality grasses.

The grazing strategy for maintaining animals through the dry season depends on its duration, the quality and quantity of the dry grasses, and the availability of shrubs and legumes. Animal response during the dry season has not been defined for many different tropical conditions, and is often confounded by limited animal intake associated with heavy grazing. If shrubs and other woody vegetation are available, as is generally the case in Africa, performance during the dry season also depends upon the animal species; cattle are the most susceptible to dry-season deficiencies, and goats and camels least. There is therefore need for a much more systematic study of factors that influence the dry-season performance of animals.

Spatial Variations of Forage Growth

In the arid and semiarid rangelands, variation in forage growth from one place to another is often great, which is a result of the different soil, slope, and rainfall patterns. Awareness of these patterns is important to effective rangeland assessment and range management planning. Developed countries have come to use range or ecological sites to express these variations in forage growth at the management level. The size of these range sites is such that the land units have practical value in grazing management and yet are not so large that similarity of soil and vegetation is lost and thus becomes more difficult to manage. See chapter 5 for further discussion of the importance of mapping scale.

Animal Control and Grazing Management

The vegetation characteristics described above need to be related as much as possible to the grazing-management strategy. Some of the more important grazing aspects are intensity, timing, distribution, and sequence.

Intensity of Grazing

Grazing intensity is a function of the number of animal units per unit of area. It is often used as an expression of the amount or proportion of forage that has been used or the residue remaining. As intensity of grazing increases, utilization of the vegetation becomes more uniform; intake per animal drops sharply when a certain threshold quantity of palatable forage is reached for each species and kind of animal. During the time of active plant growth, forage quality and opportunity for selection decrease as the vegetation is grazed to shorter stubble heights. Fresh regrowth will be of high quality and avidly selected, but the plant will be susceptible to severe damage. Prolonged heavy grazing always changes the composition of the vegetation and often changes the plant's growth form. For example, some grasses become more prostrate and shrubs appear hedged. If overuse continues, the plants eventually die.

It is possible to define the desirable intensity of use for a given area and therefore its approximate proper stocking rate. Figure 19 illustrates biological response curves for balancing livestock with vegetation to optimize production using ungrazed forage and animal gains as the criteria. Due to variations in forage yield, options for fluctuating stocking rates should be maintained. Heavy grazing during drought is inevitable, but an early reduction in animal numbers helps to assure maintenance of at least a breeding nucleus and causes less damage than does letting animals die for lack of feed.

Timing of Grazing

Timing of grazing is primarily concerned with the effects of defoliation during different parts of the growing season and the dormant or dry season. Special consideration may be given to grazing during flowering, seed set, and early growth. Use may be quite heavy during the early wet season if grazed plants can regrow, and where the dry season is relatively short. Only during the rainy season in much of the tropics can livestock gain weight. One way to accomplish increased animal growth is to use the vegetation fairly intensively, which postpones its decrease in quality. By concentrating animals and rotating grazing on part of the range, other areas can be left for use during the dry season and burned at about the time the rains are expected to facilitate new grass growth, or otherwise allowed to improve.

Due to the high quality of forage during the growing season, every effort should be made to maximize production functions during this time including parturition, lactation, growth of young animals, and breeding. If necessary, rationing by dividing the herd into groups should be applied in order to best meet critical needs. However, when provisions for milk and meat for human consumption must be on a daily basis, continuous year-round breeding and lactation are required.

Achieving adequate utilization of rangelands during the dry season is a critical problem in the humid and dry savannas. Supplemental feeding with a protein concentrate or farm by-products may be effective, but use of tropical legumes and fodder shrubs is becoming widely practiced. Separating animals into groups according to their specific requirements and productive functions, such as for milk and growth, should be a basic consideration. In general, the objective is to use management systems

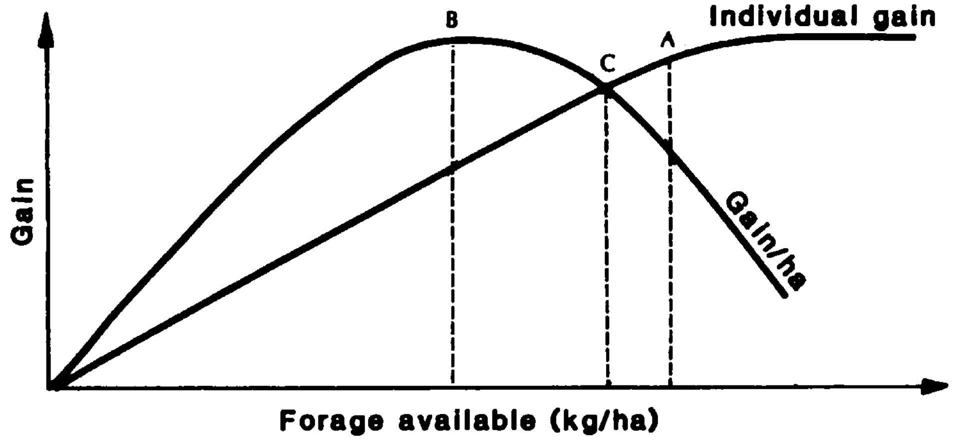


Figure 19. *Individual animal grazing and gain per hectare are shown with increasing amounts of ungrazed or available forage on a conceptional basis. The left side of the figure indicates insufficient feed for animal gains. With increasing feed, animals gain in weight, reaching to a maxima at points A and B. At point C, the animals are in balance with the forage and optimum production of both vegetation and animals is attained. Point C is the proper stocking rate. It can be approximated with relatively few data points on the two curves and continually adjusted as additional data become available. This procedure by Bement (1981) provides a flexible and practical procedure for determining stocking rates in response to changing forage supplies.*

that match animal requirements as closely as possible with the annual fluctuations in forage quality and supply and with the physiological requirements of the preferred fodder plants.

Distribution of Grazing

Distribution of grazing, in the sense used here, is concerned with the use of grazeable plants over the whole area. When grazing is uneven, usually spots will be damaged through overgrazing and others will go unused. For any stocking rate, the better the distribution of grazing, the greater the benefits will be and the less the vegetation will be damaged.

The best control of distribution of grazing can be achieved by herding and using a combination of domestic species with different food habits that are coordinated with the food habits of game animals. This ensures a variety of plants, which fit differences in the forage preferences and traveling capacities of the various animals as has been explained in chapter 3. Besides herding, control of distribution is principally affected by watering facilities. In developed areas, fencing and sometimes feeding protein supplements, molasses, or special plantings may alter grazing distribution. The presence, absence, or inadequacy of controls on watering facilities is a primary influence on distribution and intensity of grazing that has resulted in overused, underused, and mismanaged rangeland throughout the developing countries.

Sequence of Grazing

Application of sequences of short grazing periods during a growing season has been implied in several examples given above. Although usually difficult to implement on rangelands, it is one of the most important techniques for increasing the effectiveness of forage use. Small and intensively managed pastures in dairy production are the easiest for applying short-term and repeated grazing. The value of these grazing patterns depends on matching the variation in forage composition and quality from plants that quickly regrow with animals that can make immediate use of that high-quality feed. Herders can be trained to follow rotational systems without fencing and with only scattered markers to indicate pasture divisions.

Grazing Management

In the world's press and some scientific writings, it has been stated that the grazing of domestic animals may have created more land degradation and even deserts than any other land use. If this is true, it is in part because grazing is the most widespread of all land uses, especially on the poorer lands, which are often highly susceptible to injury. However, global desertification is still a matter of conjecture. In local areas, degradation has occurred, but the damage has not resulted from animal grazing per se, but as a result of too many animals on a given area, without management. The importance of proper stocking and management cannot be overemphasized.

Whatever grazing system is adopted or developed for a specific area, care must be taken to minimize conflicts with other uses. This not only applies to the grazing animals themselves, but also to the movement of these animals from one area to another, and the physical structures necessary for the success of the grazing system. Vegetation, climate, and growing season are so varied that no single grazing prescription fits all ranges. Grazing prescriptions on a general basis are described as follows:

- Continuous seasonal and continuous yearlong grazing means grazing a given area year after year throughout the active growing season of the vegetation, or for the entire year. This allows for no planned plant rest during the growing season. Due to animal preferences for certain plants, there may be a shift in the vegetation composition from desirable to increasingly poor species more than in other systems. On large range areas, where stocking is moderate to low, continuous grazing is quite acceptable, especially until development can proceed to a point where a more intensive form of grazing management may be implemented. Continuous grazing has been practiced for centuries, often with a degree of rotation by herding, around permanent villages in developing countries. Damage is mainly due to too heavy stocking, faulty distribution, and concentration near water and night corrals rather than to continuous grazing.

- Deferred grazing is a schedule in which a given portion of an area is not grazed until the latter part of the active growing season. It provides a little rest from grazing during the growing season for one pasture, but other pastures may receive heavier use than under continuous grazing.

- Deferred-rotation grazing means that a given area is divided into two to four pastures or paddocks, and grazing animals are rotated among the paddocks with one or more portions being deferred from grazing for a part of the growing season. Deferment of pastures is rotated on an annual basis; deferred pastures are not grazed until the dry season. A modification of this grazing system would be where blocks of land are set aside as grazing reserves and are regularly not used during the growing season. This practice has been used with success in northern Somalia. Rest-rotation grazing is still another variant of deferred-rotation grazing. The area is divided into three to many portions and the grazing animals rotated from pasture to pasture, with one or more portions not grazed until the next growing season. The more pastures that are available, the more sophisticated this system can be. It often combines continuous, deferred, and no grazing at all into a schedule that takes 3 to 5 years for completion.

- Restricted-growing-season rotation is a system for reducing damage to the vegetation while increasing nutrient intake. Each pasture unit is grazed for a short time and the animals moved to another pasture, perhaps for several cycles in a year. Much of the damage to ranges during the growing season is due to animals grazing the same areas repeatedly or concentrating on localized sites, which sharply reduces vegetation growth. Rather than full utilization of an area before moving on, animals should be moved in such a way as to cover the whole area available at least once during the growing season. The system optimizes the possibility for animal selection of the most nutritious parts of the plants with minimal damage. It is also adaptable to a sequence of grazing by animal groups of different categories. This practice is a way of increasing benefits from herding, but it requires organization, collaboration, and thorough understanding of the impact that grazing has on plants.

- The hema system of rangeland grazing uses reserves for five different types of protection: 1) complete prohibition of grazing, but grass cutting allowed during specific periods and times of drought; 2) grazing and cutting restricted to certain seasons of the year; 3) yearlong grazing with the kind and numbers of animals specified; 4) grazing restricted until after flowering to allow beekeeping; and 5) grazing restricted to protect trees. The ahmia (plural of hema) were originally administered several hundred years ago by provincial amirs or other tribal authorities and were in part successful because of the control on ownership and use exercised by these authorities. The ahmia systems were accepted because they provided forage in times of drought emergencies. This system has been revived through the organization of ahmia cooperatives in Syria, where grazing is controlled by the cooperatives and limited to animals owned by its members (Draz, 1983). The grazing reserves as used in northern Somalia may be considered a variant of the hema system, as well as a type of deferred-rotation grazing.

Figure 20. *Planted trees are here being raised for lumber and firewood with wide spacing that permits abundant growth of forage grasses and grazing.*

The main defect of the above systems, especially for use in developing countries, is their rigid application. Most of them have been developed in situations where fencing and rigid boundaries were normal conditions. They require considerable understanding of plant and animal responses to forage and weather conditions. Their lack of flexibility, especially in drought times, has caused many failures. Any system selected for use in the tropics must be accompanied by an educational effort from the beginning that involves the people who own the livestock, who control the lands, and who are included because of subsidy support and governmental administration.

Wildlife management has been covered in some detail in chapter 3. From the standpoint of grazing management, the most important wildlife aspect to consider is the stocking rate. The combination of game animals with domestic stock should not exceed the appropriate combined stocking rate. This means that if game animals are an important asset in a development area, provision should be made for their management, and particularly for their adequate harvest.

Agroforestry

The task of maintaining and improving the productivity and sustainability of the natural resource base, while simultaneously boosting world food production, is one of today's most difficult challenges. The concept of agroforestry, which emphasizes production of food crops, forage, and forests on the same land base, promises to be one of the most effective responses to this challenge. However, this potential can only be developed through an interdisciplinary process that will lead to multiple-use management of the world's forests. The process cannot begin in earnest until scientists and managers overcome patterns of traditional thinking that have created institutional barriers that obstruct interactions among agronomists, foresters, range managers, social scientists, animal scientists, and wildlife scientists.

Over the centuries, native cultivators in the tropics evolved a system of sequential agroforestry for use on tropical soils of low fertility. Shifting cultivation involves three steps: cutting and burning trees, growing crops in cleared areas for 1 to 5 years, and fallowing the area for 5 to 12 years to permit the regrowth of native vegetation and to rejuvenate the soil (see figure 21). Shifting cultivation is primarily a system of nutrient conservation, accumulation, and recycling, but it also provides wildlife habitats and a source of wood for fuel as secondary benefits. Although shifting cultivation appears primitive, it has permitted sustained production for generations and is a good base for developing more advanced agroforestry systems, including planting selected food-producing trees or livestock fodder trees in the fallow area instead of allowing natural invasion. These traditional systems are serving as the base for developing many of the future approaches to agroforestry in the tropics.

The agroforestry livestock situation in developing countries tends to be similar because most cultivators have a few animals. However, many African countries also have considerable interest in wildlife. Efforts to integrate livestock into agroforestry have focused on two areas: growing and using fodder trees and shrubs as a conservation practice; and grazing livestock under tropical tree crops, e.g., timber, rubber, coconut, and oil palm.

Interestingly, an agroforestry approach is being taken to counter desertification and deforestation both in semiarid and in humid locations. Rapidly growing trees are being planted to stabilize the soil, to supply forage for livestock, to be used for fuel, and to produce some wood products. Researchers are actively promoting leguminous trees such as *Leucaena leucocephala* that will supply forage, fuel, fertilizer, and wood (more than 100 m^3/ha/year as compared to temperate pine plantations, which produce 10 m^3).

Integration of tree crops and livestock has been studied throughout the world. Dairy cattle have been kept in old coconut plantations in Tanzania. In Malawi, such legumes as *Stylosanthes guyanensis, Macroptilium atropurpureum,* and *Desmodium uncinatum* are grown under rubber trees as a seed source. In West Africa, studies have included: grazing sheep under 15-year-old oil palms and Kola trees that had yet to form a closed canopy; sheep in a mango/cashew plantation; and cattle in palm groves.

Agroforestry is entering a period of transition in response to increasing pressures on the earth's natural resource base to supply a broad range of goods and services essential to man's well-being. Although forest grazing is a traditional method of multiple use, it has been characterized by few, if any, management inputs and by low levels of productivity. Since the opportunistic approach is not likely to meet future needs, more advanced production systems with greater management inputs must be developed and implemented.

The numerous approaches being taken to improve agroforestry production systems can be grouped into five management-oriented categories: 1) planting fodder trees and shrubs to slow deforestation in the humid tropics and desertification in the arid tropics; 2) producing forage on pine plantations in temperate conifer forests; 3) integrating forage production with tree crops (common in the tropics but also found in orchards in temperate zones); 4) managing forests for production of wildlife used for food; and 5) reducing grazing damage on broadleaf forests in both tropical and temperate zones.

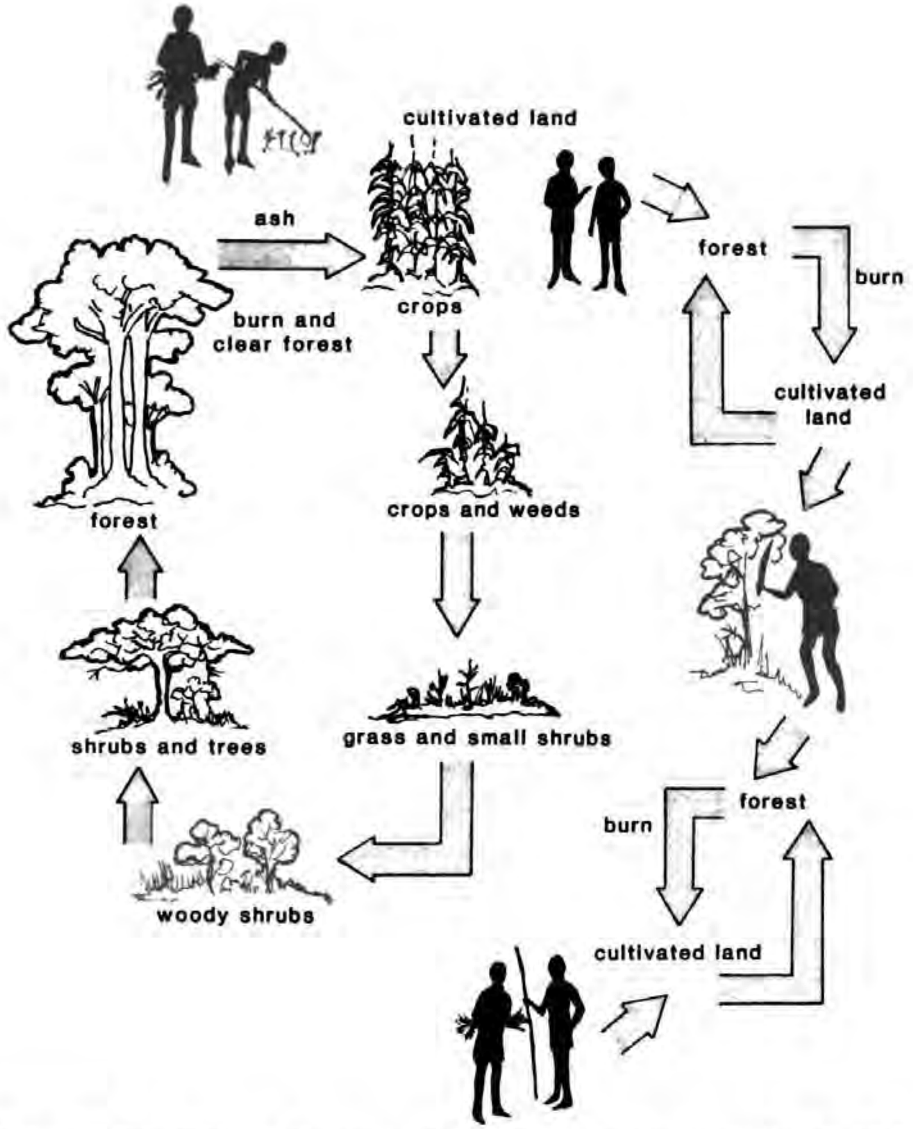


Figure 21. *The shifting-cultivation cycle (redrawn from Heady and Heady, 1982).*

The above approaches represent only a loose collection of observations resulting from research and management activities scattered around the world. The knowledge currently available has helped solve many local management problems, but it is neither of sufficient detail and scope, nor adequately organized, to provide an understanding of the structures and processes linking the various social, economic, political, and biological components involved in agroforestry production systems. Such an understanding is essential if findings at one location are to be extrapolated to solve problems at other locations.

Resource Development

Resource development requires the planning, layout, and construction of the structural improvements necessary for the management and control of grazing and other uses to be made of a given area. In the preparation of the plan, the effects of each development item should be considered together with interactions among developments. For instance, the impact of roads and permanent water should be considered in relation to the effects of likely concentration of people and domestic animals. The plan must include details beyond those mentioned in chapter 4 and emphasize the following: 1) multiple-use objectives of each development; 2) interactions of people, wildlife, and domestic animals; 3) size, number, and location of each type of infrastructure; 4) likely problem areas; 5) initial, annual, and long-term financing; 6) priorities for development, construction, and implementation; 7) inspection and follow-up; 8) administration and enforcement; and 9) maintenance.

As has already been suggested, the success of any project will depend upon the goodwill of the people. It is the local people who will need to be prepared to carry on activities initiated by the project. Their reasons for doing things a particular way are frequently practical. Water developments and transportation infrastructure are principal types of aid that can meet the needs of many people, but are susceptible to abuse without maintenance and continued administration.

Water

Water in the right place and in the right amount is crucial to the development of nearly all range areas. However, errors in water development have caused varying degrees of environmental degradation, probably more than any other type of structural improvement. In semiarid and arid regions, water has always been scarce and difficult to obtain. People live near water, regard an abundance of it as desirable, and believe that the sight of it has great value. Therefore, the tendency has been to develop as many large wells with excessive water flow as was financially possible. Such conditions invariably led to concentrations of animals and people, which if not disastrous to the project, caused later management problems and land destruction.

The size or capacity of any given water supply therefore becomes an important consideration. Large amounts of excess water should be

Figure 22. *Water attracts wild animals as well as it does domestic animals — in this instance for public viewing in Tsavo National Park, Kenya.*

avoided. Total water-delivery capacities should be carefully calculated to fit the projected use and period. For example, a mature cow with a suckling calf may require as much as 40 liters to 50 liters per day, and a sheep up to 4 liters or 5 liters, varying with temperature and humidity. Add to these requirements the expected losses by evaporation and seepage, and the result is the water needed for each animal.

The planning of new water developments should take into account those already in existence and the traveling distances of people, wildlife, and domestic animals. As a general guide, one may assume that walking distance to water should not be more than 6 km for animals. However, this will vary according to topography, time of year, and animal species. In arid areas where nomadism is the way of life, water developments must be widely spaced and carefully managed.

Infrastructure

The infrastructure consists of basic engineering installations, facilities, and roads necessary for the development and functioning of the project. These elements must be properly planned and well-constructed because they are vital to the everyday operation and eventual success of all projects. The extent and type of structures depend on such factors as the number and kinds of uses, administrative and educational contacts that need to be maintained, marketing requirements, and movement of produce. The infrastructure should be planned in detail concurrently with the production activities to be carried out and projections of future requirements.

At least a minimal system of all-weather roads is necessary for supplying materials, marketing commodities produced, and for general travel of the people. Most often improvements in the size and location of existing roads is all that is needed. In other situations new roads will be required for new developments.

Where handling of livestock becomes necessary, holding pens, scales, and dipping vats should be planned according to projected needs. Such facilities must be strategically located at population centers, used in conjunction with other aspects of the project, and made of local materials wherever possible.

On most projects, permanently assigned personnel should be designated to live within the work area, and new or reconstructed dwellings as well as other requirements for living will be essential to the well-being and productivity of these personnel. Such dwellings should usually be located in conjunction with, or at least near, livestock and agricultural crop-handling facilities for purposes of security, marketing, animal health, and maintenance. Firebreaks may be essential to the facilities and project.

Fuel and Charcoal

Wood from rangelands is a major source of fuel, either as dry wood or as heat-processed charcoal. Manufacture of charcoal is in sealed kilns that permit small flows of air sufficient to support the carbonization process but not enough for flaming. The first phase is burning, which takes 1 to 4 weeks. The kiln is then sealed and allowed to cool. Typically, 100 kg of charcoal results from 1 m^3 of wood. The kilns may be small and locally made of soil and poles, or more elaborate and made of metal. Charcoal operations often accompany brushland clearings, in which case excavation and charcoaling of stumps can reduce stands of undesirable sprouting woody species. Charcoal production helps cover the cost of converting brushlands to more open forage resources (Little, 1972).

Other Developments

Many areas produce, or can produce, sufficient trees so that some aspects of a timber industry may provide additional small-farm income. Improvements in combinations and management of trees, crops, and pastures grown together hold great promise for villagers in savanna and forest regions. Their basic culture for centuries has been diversified cropping, which is an example of multiple use. Changing to a monoculture form of farming in project areas frequently fails and should only be done after careful analysis and determination that the people will accept cultures of pure crops. In semiarid and arid regions, woody plants are frequently of major use for fodder, fuel, human foods, and soil improvement. Depending upon the number of trees per acre and the size of the trees or shrubs, these tree products may also be sold as timber or processed into charcoal. Growing woody plants may be either a large-scale operation or a continuing cottage industry. In either case development facilities of many types may be required.

Range Improvements

Direct improvement of rangelands refers to the series of practices that result in the betterment of the overall vegetation and that aid in the renewal of the natural resources for multiple-use benefits. Such improvement practices are largely in the nature of revegetation, water conservation, brush management, and prescribed fire. These are recommended when the deterioration of the vegetation and soil cannot be improved by livestock-management procedures alone. Improvement practices should only be undertaken as a last resort in semiarid and arid regions because insufficient rainfall often causes them to fail. It is far easier to maintain a range in good condition, or even to improve a badly deteriorated area through management, than it is to rehabilitate apparently destroyed natural resources. Protection and livestock control are essential for improving the range whether through direct management or range improvement.

Revegetation

Revegetation is a family of improvement practices that are utilized in the worst of the overgrazed areas, where drastic reduction in the cover of the soil surface has occurred and few root crowns of desirable perennial vegetation exist. The vegetation may be restored through natural plant succession or by seeding. The goals of revegetation are: 1) pasture improvement to increase quantity and quality of forage for livestock and wildlife, 2) improved watershed conditions, and 3) a means of providing supplemental or reserve pastures.

Natural revegetation is the improvement of the ground cover and species composition of the existing vegetation through the manipulation and control of animals by various management techniques. In some cases, it requires the alteration or removal of severe wildlife impacts, woodcutting, too frequent fire, and other unfavorable practices. Management is the cheapest and easiest, and usually the fastest means of vegetation improvement. It should be employed first, followed by seeding or planting on areas where animal management cannot do the job alone, but only after acceptable levels of animal control are assured to protect the seedings.

Artificial revegetation by seeding or planting involves introducing seeds and(or) plants that are not naturally present. Seeding is undertaken when either the existing ground cover is too depleted to reseed itself with desirable species in a reasonable time frame, or certain species are to be introduced into the plant composition.

Revegetation should not be attempted: 1) in areas where grazing animals cannot be controlled for the first year or two, 2) in arid or semiarid areas where the soil is either very shallow or relatively infertile, and where precipitation patterns are unpredictable, 3) in tropical areas of granite soils where the humus layer has been totally destroyed and(or) leached out; or 4) in areas where grazing management is impossible or where effective use of the seeded area cannot be made.

Experience with artifical revegation has shown that the following seven items are important considerations:

- The importance of using adapted plant species cannot be overemphasized. Seed of the desired native species should, when possible, be collected close to the revegetation project or within the province, or at least should come from a similar environment. Adaptation becomes even more important with introduced or nonnative species. Only those that have been previously grown somewhere in the country and have produced seed should be used. Transfer of plant species from a given climate, soil, elevation, growing season, and topography to a greatly different situation usually results in poor germination, high seedling die-off, and low plant survival. Depending upon the species, a few surviving plants usually require numerous successive generations before the species becomes adapted to locally prevailing conditions.

- Each particular ecosystem has its own set of native legumes, which may be trees, shrubs, or forbs. In many cases the native forage legumes have been destroyed because of their high palatability. Legumes are crucial to the increase of nitrogen available in the soil, and any revegetation attempt should include them in the seed mixture. Many tropical and subtropical legumes are available for the humid tropics.

- The reduction of competition for water and soil nutrients by undesirable vegetation is an important consideration in revegetation attempts. This may be accomplished by cutting sprouts of woody plants, or cultivating or hoeing the soil prior to seeding.

- Time of planting depends upon the rainfall pattern. In general, planting should be done so that seedlings emerge at the time when rainfall continuity is most likely. For example, in areas of winter rainfall (Mediterranean climate), it is best to plant in the autumn. In areas having fairly reliable summer storms, it is best to plant in the spring. Just as with crops, the seedlings of forage plants need to grow sufficiently large to withstand the stress of the dry months.

- Seedbed preparation is essential for good germination and seedling survival. Grasses and other plants with small seeds require a compact and firm seedbed.

- The depth of planting is directly proportional to the size of the seed being used. Very fine seeds should be barely covered, not over 5 mm deep. The larger seeds should be planted deeper, the largest to about 2 cm.

- The method of planting depends upon the size of the area to be planted, coincidental treatments such as brush control, type of seedbed preparation, and the equipment available. Hand-seeding and planting are usually the methods used in village agriculture.

On small areas, hand-broadcasting or using a small hand-held whirlwind type of seeder is best. Seed should always be covered with a brush or hand rake. If heavy equipment is to be used for brush removal before reseeding on large projects, seeders are available that work off the heavy equipment itself.

Water Management and Conservation

Rangelands serve as watersheds that provide groundwater recharge and overland flow for downstream water uses. Consequently, both the soil and the vegetation should be maintained in the condition for optimum, clean water yield. When watersheds are not so managed and maintained, the effects can be damaging in the short term and costly overall. Bare soil often becomes so compacted that infiltration and groundwater recharge are drastically reduced, even to the point that wells for domestic and irrigation water must be continually deepened or other water sources found. The objective should be to manage for a loose and crumbly soil surface that is covered with plant materials.

The existing vegetative cover is dependent upon the soil, climate, and past history of use. Vegetation occurs in layers over the soil surface; the uppermost layer (overstory) slows the fall of the raindrops, intermediate-level leaves further slow the fall, and the litter or ground cover breaks the impact of the falling raindrops. A raindrop missing these layers strikes bare soil, creating a splash that dislodges soil particles. Dislodged particles are filtered by the soil itself, thereby creating a dense crust, and further reducing infiltration. When the vegetative cover decreases over large areas, erosion begins and the quality of the runoff water decreases because of increased sediment and minerals. Because deterioration continues, runoff waters become progressively less useful for irrigation and other uses. Management objectives should be to produce and maintain vegetational cover to prevent erosion and ensure adequate infiltration.

Where severe erosion has occurred, special control measures will be needed until management can improve the situation and maintain the soil. Delaying proper management permits erosion to accelerate, creating situations that require more massive effort, larger structures, and greater expenditure of money. It is useless to undertake these measures when the root of accelerated erosion is overgrazing. The more common forms of erosion control are:

- Revegetation: On many areas accelerated soil movement occurs as sheet or rill erosion because of reduced ground cover. This may be stopped or at least greatly reduced by increasing the ground cover of perennial grasses and forbs through revegetation techniques.

- Structures: Where erosion has progressed to the point of massive sheet and rill erosion and gullies have been formed, use of engineering structures such as gully plugs, dikes, terraces, and dams may be necessary. The methods chosen depend upon financing and availability of hand or machine power.

- Mechanical soil treatment: When stream erosion is occurring as a result of poor infiltration and increased runoff from the upper watersheds, mechanical treatment in the form of pitters, offset disc pitters, imprinters or various types of rippers, and water spreading are sometimes effective. Treatment of the upper watersheds by these means increases infiltration, decreases runoff, and greatly contributes to improved downstream water quality. Soil treatment usually requires heavy equipment.

Brush Management and Control

The need for brush management or control may arise as a result of a number of factors. Various multiple-use aspects of a given area, such as road construction, structures, farming, wildlife, and domestic animal grazing may require clearing, thinning, or complete brush removal. In one form or another, and for a number of reasons, brush has become very dense on much rangeland. Some dense stands may preclude other types of vegetation and even become impenetrable to man or animals. When brush species reach a density that necessitates control measures, the ground cover of grasses and forbs has usually been reduced to the point where revègetation may be necessary following treatment. Different woody species require different control techniques. Goats are particularly useful for the control of shrub species reasonably palatable to them. Time, intensity, and duration of goat browsing influence effectiveness.

Figure 23. *Soil pitting on rangelands reduces runoff and provides water in the pits for establishment of seeded forages. Frequently, nearly level, bare land so treated will rapidly develop a plant cover.*

The sprouting species that grow from underground bud zones are the hardest to control. For the larger sprouting species the root plow is best suited and for the smaller sprouting species the brushland plow is adequate. Seldom if ever does a single treatment obtain anything like a 100% kill. One or more subsequent retreatments is usually necessary, although the retreatment technique need not be the same as the first. The sprouting species are very common in tropical and Mediterranean climates and practically preclude effective brush control by mechanical means. Chemicals and fire are more effective.

Nonsprouting species that reproduce solely by seed are the easiest to control. For large tree-sized nonsprouting species, the jungle buster or anchor chain between two D8 or D9 Caterpillar-type tractors is an effective treatment. For small trees, shrubs, and half-shrubs of nonsprouting species, the Marden brush cutter can be an adequate means of reducing brush cover. Large-scale application of herbicides requires a spray-equipped fixed-wing airplane, helicopter, or ground rig. An on-site storage area together with mixing facilities and either a landing pad or runway are needed in the cases of the helicopter or fixed-wing airplane. These facilities can be provided only on very large projects. In small areas where brush density is not great, the individual plant treatment by the hand-application of pelleted herbicides is acceptable. Care must be exercised in meeting local regulations concerning the use of specific herbicides or pesticides as well as in the control of grazing after spraying.

In varying degrees hand control using on-site or local labor is advantageous. In individual tree applications with backpack sprayers or pelleted herbicides, the saving in costly herbicides frequently more than pays for the cost of application. In large-trunked sprouting species, digging out the individual stumps by hand is the surest control measure and is also frequently cheaper than using heavy equipment. The use of hand labor involving local people develops enthusiasm for the project(s) and provides a certain amount of revenue.

In the absence of fire, many grasslands, especially in savanna ecosystems, tend to become dominated by shrubs. Palatable shrubs are desirable and moderate quantities of them are acceptable. Others have little value to most herbivorous animals. Increasing shrub density eventually results in a sharp reduction in the carrying capacity for those animal species that depend mainly on grass. The use of fire to prevent the succession from moving too far toward brush dominance is the cheapest and frequently the most effective method for brush stand manipulation.

Prescribed Fire

Fire is a valuable management tool to be used in conjunction with grazing management. When used in such a way, it can contribute substantially to rangeland maintenance and productivity.

Fire may be used either to control or to manage vegetation. In control, the objective is to eliminate or greatly reduce the amount of woody vegetation on a given area. The aim is conversion from one vegetational type to another. In management, the objective is to maintain the density or number of certain plants per unit of area at some desired level. Another management use of fire is to reduce accumulations of low-quality and mature grass biomass, making new feed readily available. These objectives may be achieved where sufficient fuel buildup exists by controlling the heat and rate of burn. Before using fire as a management tool, consider the following factors and relationships.

Atmospheric conditions, especially air temperature, humidity, wind velocity, presence or absence of cloud cover, and prevailing wind direction determine the rate of burning. Climatic criteria for burning or not burning need to be established and followed for each location.

Ground cover in the semiarid and arid rangelands is frequently too sparse to carry a fire of sufficient intensity to produce the desired vegetational changes. If a fire is necessary, remove all grazing animals for a wet season to allow adequate ground cover to grow.

Soil sterilization might occur when large amounts of dry woody materials burn for a long time, but seldom is the buildup of flammable materials that great in dry forests and savannas of the tropics. The ash from such fires is white and has certain fertilizer properties.

Species sensitive to fire are mainly nonsprouting plants. A slow, hot fire may therefore destroy nearly all of them. If these species are highly desirable, use fires only when burning conditions allow a faster, cooler fire, or use no fire at all.

Some species require fire for germination or sprouting. Fire may be used on them to stimulate seed germination or increased forage production through sprout production. Some basic knowledge of the plants' reaction to fire may be acquired through consultation with local pastoral peoples.

Volatile oils and waxy coatings on leaves and bark of numerous Mediterranean shrubs result in a hot fire under uncontrolled conditions. These volatile gases frequently are carried some distance from the original burn and can ignite to start secondary, unplanned fires.

Inasmuch as a freshly burned area with young grass attracts all grazing animals in the area, overgrazing and a consequent reduction in plant growth is common on small burned areas. This may lead to excessive soil compaction and increased runoff and erosion. Fires in the tropics should cover a large enough area to prevent such animal concentrations.

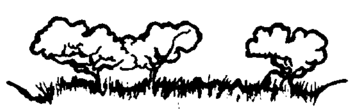
Besides its widespread use to control brush, fire is an integral part of managing to improve quality, palatability, and availability of herbaceous forage. Fire is widely applied to accumulations of dry material just before the beginning of the growing season. The emerging grass soon becomes available to animals and is of higher quality than it would be without the burn. Burning may also be used for a variety of other reasons such as providing a habitat suitable for particular animal species, influencing animal distribution, reducing populations of ticks and other insects, and favoring certain species of plants.

Integrated Rangeland Management

The rangelands of the world are extremely varied and every management unit (ranch, pasture, grazing district) has a unique set of management goals, environmental characteristics, available external resources, and combination of basic ecological principles that apply. Before a successful management strategy developed for a particular unit of rangeland can be adopted on another unit of even similar land, the principles and goals critical to the strategy's success must be evaluated.

Good range management views each management unit as a unique ecosystem and uses basic principles from many disciplines including ecology, economics, political science, and sociology. The art of combining these principles into a management strategy that considers the whole ecosystem has been referred to, with minor variations, as holistic resource management, the ecosystem approach, multiple use, integrated resource use, or range management. Whatever the term used, it is this approach that is important to the sustained productivity of the vast rangeland resources to meet the short- and long-term needs of man.

Table 6. Key Management Problems and Recommended Practices by Rangeland Systems

Systems	Grazing Systems*	Water Development	Soil Conservation	Prescribed Burning	Woody Plant Control	Plants for Seeding
Savannas with tall grasses 	Deferred-rotation, trans-humance, nomadic hema, con-tinuous	Surface storage or wells required	Maintain soil cover	Use widely	Charcoaling, mechanical, chemical, prescribed burning	Only a few grasses and woody legumes available
Deciduous forests with high grasses 	Deferred-rotation, trans-humance	Surface storage or wells required	Maintain soil cover	Use frequently and widely	Charcoaling mechanical, chemical, prescribed burning	Many improved legumes and grasses available
Desert shrub and grasslands 	Nomadic, herding, hema systems	Surface storage or wells required and of first priority	Water-spreading and water-har-vesting struc-tures to improve cover on selected areas	Use infre-quently	Fuelwood harvesting only	Shrubs on selected sites
Seasonally flooded and wetland vegetation 	Save for dry-season grazing	May be useful sites for development	Control gullies in central channels	NA	Seldom a problem	Seldom seeded

Systems	Grazing Systems*	Water Development	Soil Conservation	Prescribed Burning	Woody Plant Control	Plants for Seeding
Tropical rainforests 	Coordinate animal use on pastures and crop-land	Usually plentiful	Maintain soil cover	Use in land clearing	Charcoaling, mechanical, chemical, prescribed burning	Tropical legumes and grasses available
Winter rainfall vegetation 	Deferred-rotation	Usually plentiful stored water and wells in dry season	Maintain soil cover	Use for clearing brush	Mechanical or chemical for fuelwood	Cool-season grasses and clovers available
Montane forests 	Rotational grazing	Usually plentiful	Maintain soil cover	Use infre-quently	Mechanical and chemical clearing to develop pastures and cropland	Use only cool-season grasses and legumes

*Refer to description in this chapter.

Annotated Bibliography

Bement, R. E. 1981. Biological Response Curves for Balancing Livestock with Vegetation. In: Food Production Systems and Environmental Rehabilitation in Somalia. Somali Research Group. Arlington, VA.

This paper develops a concept for determining proper stocking rates.

Branson, F. A., G. F. Gifford, and J. R. Owen. 1981. Rangeland Hydrology. Range Science Series No. 1 (Second Ed.). Society for Range Management, Denver, CO. 340 pp.

Several authors give up-to-date reviews of the principles of hydrology on rangelands. Much applies to tropical rangelands as well as to temperate zones.

Draz, O. 1983. The Syrian Arab Republic Rangeland Conservation and Development. World Animal Rev. 47:2-14.

The history and use of the hema system are reviewed.

Heady, H. F. and E. B. Heady. 1982. Range and Wildlife Management in the Tropics. Longman Group Ltd., London. 140 pp.

This short book describes principles and practices of rangeland management for diploma-level students. It is illustrated with black-and-white photos and suggests many publications for further reading.

Humphreys, L. R. 1978. Tropical Pastures and Fodder Crops. Longman Group Ltd., London. 135 pp.

Legumes and grasses used in seeding pastures and rangelands are described in terms of their forage value and culture including seeding, fertilization, planting mixtures, seed production, and grazing management.

Little, E. C. S. 1972. Kenya Bush Control. United Nations Development Program/Food and Agriculture Organization (UNDP/FAO), Nairobi, Kenya.

Summarized work on controlling bush, including charcoaling as a means of reducing control costs.

Moris, J.R. 1981. Managing Induced Rural Development. International Development Institute, Bloomington, IN. 190 pp.

This book has 10 chapters that discuss the development process in rangeland areas. Chapter 8 presents an excellent case study of the Maasai Range Development Project. This project was sponsored by USAID in three phases running from 1970 to 1980. The case study offers several lessons learned from rural development programs generally.

Pratt, D. J. and M. D. Gwynne. 1977. Rangeland Management and Ecology in East Africa. Krieger Pub. Co., Huntington, NY. 310 pp.

The 25 contributors describe rangeland vegetation, principles of use, management, rangeland improvements, livestock enterprises, and wildlife relationships in a technical yet readable form. The reference list is extensive.

Sandford, S. 1983. Management of Pastoral Development in the Third World. John Welly and Sons, New York. 316 pp.

Many guidelines to grazing management are given.

Stevens, M. E. 1976. Erosion Hazard Classification and Inventory Techniques in Mountainous Areas. FAO Conservation Guide 2:13-21.

The Conservation Guide series, especially numbers 2 and 3, contain many papers on erosion control, water management, and soil conservation in tropical areas. Rangelands and forests, as well as cultivated land, are included.

Wont van den, Bor (Ed.). 1983. The Art of Beginning. Pudoc Wageningen, P.O. Box 4, 6700 AA, Wageningen, Netherlands. 174 pp.

This book contains 12 case studies giving the first experiences and problems of western expatriates in developing countries, with special emphasis on rural development and rural education. It also contains an annotated bibliography of other case studies.

Glossary

A

ABIOTIC. Non-living, basic elements and compounds of the environment, such as water, solar radiation, minerals, etc.

ADAPTATION. A measure of physiological fitness or degree of adjustment of an organism to its environment. May be determined by physiological characteristics, structure, and activities.

AGROFORESTRY. The production of trees for wood, food crops, and(or) cultivated forage on the same land.

ALLUVIAL. Pertaining to soil or geological material deposited by running water.

ANIMAL HUSBANDRY. The science of breeding, feeding, and tending domestic animals, especially farm animals.

ANNUAL. A plant that completes its life cycle from seed within a single year.

ANNUAL GRASSLANDS. Lands on which the principal plants are annual grasses, which complete their life cycle from seed within a year or less.

AQUACULTURE. The cultivation of fish and other animals and plants in controlled marine environments.

ASSESSMENT STRATEGY. The selected approach for appraisal or evaluation — as for the assessment of natural resources.

B

BASELINE STUDIES. Studies made to provide data against which future studies may be compared, e.g., to measure change.

BIOMASS. The total mass of living plants and(or) animals existing at a given time in an area, or ecological unit (e.g. total aerial biomass of vegetation, large-mammal biomass, etc.).

BIOTIC. Refers to life, living.

BOREAL FOREST. A northern forest consisting chiefly of conifers.

BROADLEAF FOREST. A forest of deciduous or evergreen trees having broad or flat leaves.

BROWSE. Leaves, twigs, and shoots of shrubs, woody vines, and trees available for animal consumption. "To browse" is to consume browse.

BROWSERS. Animals that use woody plants for a major portion of their diet.

BRUSH, SPROUTING SPECIES. Brush species with basal buds, often underground, from which new shoots emerge, especially when old shoots are removed.

C

CAMELOIDS. Large, domesticated, humped-back mammals. There are two species, *Camelus dromedarius* (dromedary or arabian, with one hump) and *Camelus bactrianus* (bactrian, with two humps).

CAMPOS CERRADO. A heterogenous vegetation type, occupying 20% of Brazil's land area, composed of scattered trees and shrubs and seasonal grassland, characterized by very low soil fertility.

CANOPY. The aerial portion of shrubs and trees, usually expressed as percentage of ground that would be covered if a vertical projection were made. Closed and open canopies express relative degrees of cover.

CLIMAX PLANT SPECIES. Plant species found in plant communities that have reached the final (climax) successional stage.

COLD-BLOODED. Animals whose blood temperature varies according to the temperature of the surrounding medium, e.g., snakes, lizards, and fish.

COMMUNAL. Belonging to a community or small group of people.

COMMUNITY (BIOLOGICAL). A group of one or more populations of plants and animals with a common habitat.

COMMUNITY STRUCTURE (PLANT). The vertical and horizontal distribution of plant components (trees, shrubs, herbaceous, etc.) in a community — including the growth forms, stratification, and principal species.

CONSERVATION. The use and management of natural resources according to principles that ensure their sustained, high economic and(or) social benefits without impairment of environmental quality.

CONSUMER. One who uses goods or services to meet his/her needs rather than transferring them or producing other goods with them.

CONVECTION STORM. Intense precipitation that results when the moisture in rapidly rising air (due to heating of the earth's surface) condenses.

CROP RESIDUE. Plant parts that remain after harvesting, clearing, and processing crop products.

CULLING. Removing plants or animals, usually of a lower quality, from the basic breeding stock.

CULTIVAR. Certain cultivated plants that are distinguished by significant characteristics and that, when reproduced sexually or asexually, retain their distinguishing features; the same as a variety.

CULTURE. 1) The body of customary beliefs, social forms, and material traits (such as housing design, clothing style, tools, etc.) constituting a distinct complex of tradition of a racial, religious, or social group. 2) The act or practice of cultivating the soil; tillage. The raising of plants or animals, especially with a view to their improvement.

D

DAMBO. The native name for small, grassy floodplains of central Africa.

DECIDUOUS. Woody plants that seasonally lose all of their leaves and become temporarily bare-stemmed.

DEFOLIATION. Removal of the leaves of plants.

DEMOGRAPHIC. Relating to the dynamics of a population, especially with regard to density and capacity for expansion or decline.

DERIVED SAVANNAS. Savannas that have been induced by external activities such as fire, drainage, overgrazing, and forest cultivation.

DESERT. An area of land that has an arid, hot to cold climate, with very sparse vegetation (usually shrubby) that gives a dominant tone of aridity to the landscape.

DESERTIFICATION. The process of desert formation, stimulated through land-use practices such as overgrazing and cultivation, which decrease plant cover and reduce rainfall.

DIGESTIBILITY COEFFICIENT. The percentage of dry-matter intake that is digested.

DIVERSITY. The state of being different; lack of uniformity — as diversity of plant species.

DOMINANT. A plant or animal species that, by means of number, size, or aggressiveness, exerts major influence on associated species.

DYNAMIC EQUILIBRIUM. A state in which populations, ecosystems, or other biological units tend to maintain each part of the system in harmony with the rest, even when undergoing change.

DYNAMIC CLIMAX. When vegetation has reached the most advanced stage of succession but fluctuates around this point of relative equilibrium in response to influences such as rainfall, fire, etc.

E

ECOLOGICAL. Of, or having to do with, living things and their environments.

EGALITARIANISM. A belief in or practice of human equality.

ENDEMIC. Prevalent in or restricted to a particular area, region, or country.

ENERGY INTAKE. The amount of energy in the feed consumed.

EPIZOOTIC. A disease that spreads quickly among animals.

ESTERO. A Spanish term for estuary, inlet, marshy area, or flooded depression.

ETHNIC. Relating to groups of people classed according to common traits and customs, which are products of heredity and cultural tradition.

EVAPOTRANSPIRATION. Loss of water by evaporation from land and by transpiration from plants.

EVERGREENS. Plants that remain green throughout the year by retaining at least some of their leaves at all times, or by having green stems that carry on photosynthesis.

F

FALLOWING. To plow, harrow, and break up land without seeding to destroy weeds and conserve soil moisture.

FIBER. An elongated, thick-walled, tapering plant cell that lacks protoplasm. Fiber cells characteristically have low digestibility.

FODDER TREES/SHRUBS. Trees or shrubs that may be harvested in part or entirely for animal feed.

FORAGE GRASSES. Grasses available for grazing.

FORAGE LEGUMES. Legumes available for grazing or browsing.

FORBS. Herbaceous plants other than grasses and grasslike plants.

FOSSIL FUELS. Hydrocarbons, derived from deposits, which may be used for fuel (coal, oil, natural gas).

G

GAME. Wild birds, fish, or animals hunted for sport or for food.

GENERA. The plural of genus.

GENETIC, GENETICALLY. Of, relating to, or involving the branch of biology (genetics) that deals with the heredity and variation of living things.

GEOLOGICAL EROSION. The normal or natural erosion caused by geological processes acting over a long period of time.

GRASS. The common name for all members of the Gramineae with characteristically reduced flowers; a grain type of fruit; narrow, usually elongated leaves that are attached in two ranks to the jointed stems; and fibrous roots.

GRASSLANDS. Lands on which grasses are the dominant plant cover. Often used synonymously with grazing land.

GRAZE. To feed on herbage such as grass.

GRAZERS. Animals that feed by grazing.

GRAZIER. A person who grazes animals.

GRAZING-MANAGEMENT PLAN. A program of action designed to secure the best use of a range.

GRAZING PATTERNS (COMMUNAL). Characteristic grazing practices and animal movements associated with any group of pastoralists.

GRAZING SYSTEMS. Grazing-management schemes based generally on the definition of the specific use that each paddock or land unit is to receive in terms of: stocking rate, or intensity of utilization; period of use; period of nonuse (deferment); density of animals; and number and character (composition) of herds. Grazing systems commonly used include continuous grazing, deferred grazing, deferred-rotation grazing, and short-duration grazing.

GROUNDWATER. Water standing in or moving through the soil and underlying strata.

GUINEAN ZONES. A belt of country in West Africa extending from the coast to about 8°N, characterized by high rainfall (mostly exceeding 1500 mm annually) and little variation in temperature. The natural vegetation is tropical rain forest. The tsetse fly severely limits livestock production in this zone.

H

HABITAT. The type of site where a plant or animal naturally or normally lives.

HEMA, AHMIA. Singular and plural terms for ancient grazing systems used in various Arabic countries aimed at achieving conservation and stability through reserves or other controls of grazing; recently reintroduced in modified form in Syria.

HERBAGE. The more succulent (nonwoody) parts of vegetation eaten by grazing animals.

HERBIVORE. An animal that eats plants exclusively.

HERD. A group of animals usually of the same species and, in many countries, under the care of a herder.

HIGH-INTENSITY STORMS. Heavy rainfall over short periods, characterized by heavy runoff and erosion where ground cover is sparse.

HOLISTIC. Emphasizing the importance of the whole and the organic-function relations of parts and the whole, e.g., considering parts of an ecosystem in the context of the whole ecosystem and not as isolated units.

HUMID EQUATORIAL FOREST. A broadleaf, evergreen, hardwood forest found in the high-rainfall areas near the equator.

HYDROLOGIC. Of or relating to hydrology, a science dealing with water.

I

IMPLEMENT. To carry out (a plan or proposal).

INFRASTRUCTURE. The underlying foundation or basic framework (e.g., the roads, telephones, radio, etc.) that link various communities.

INNOVATION. New or original approaches, i.e., as to the solution of problems.

INTERCEPTION (RAINFALL). The process by which precipitation is retained by different parts of plants before reaching the ground.

INTERDISCIPLINARY COLLABORATION. The participation of people from two or more disciplines or fields of study, in one effort or project.

INTERFACE. A common boundary or area of contact of two spaces or bodies.

INTEGRATED RESOURCE ASSESSMENT/USE/PLANNING. Taking fully into account the various related resources (including human resources) occurring in an area and their interrelationships in assessment, use, and planning.

INTERSPERSED VEGETATION TYPES. Vegetation types that, due to soil, topography, or other factors, are broken into small units scattered among or within other types (e.g., patches of forest within a grassland).

INVASION. The process by which a species migrates from one area and establishes itself in a new location; less frequently applied to animal migration.

K

KAOLINITE. A hydrous aluminum silicate that constitutes the principal mineral in kaolin.

L

LANDFORM. A natural feature of the earth's surface.

LAND TENURE. The manner or condition by which land is held, owned, or controlled.

LEGUME. A plant belonging to the family Leguminosae, having root nodules that contain nitrogen-fixing bacteria (e.g., among forage legumes: clover, alfalfa, and stylo).

LIGNIN. A noncarbohydrate, indigestible part of forages that lowers the digestibility of associated cellulose and other complex carbohydrates.

LITTER. The layer of dead, largely undecayed vegetation found on the soil surface. Most important for helping the soil absorb rain, thus reducing erosion.

LIVESTOCK FINISHING. The final phase of growing fattened livestock for the market. Usually includes the feeding of concentrates, but may be done on good pastures.

LLANOS. Open, grassy plains of Colombia and Venezuela, characterized by fairly high rainfall, a long dry season, and low soil fertility.

M

MACROCLIMATE. The general climatic conditions of a given locality such as may be determined from data furnished by most meteorological stations.

MANAGEMENT PRACTICES. The activities involved in carrying out a program of management, e.g., activities to control grazing and animal reproduction.

MBUGA. A native East African term for steppe.

MEDITERRANEAN-TYPE CLIMATE. Characterized by hot, dry summers and cool, rainy winters, this climate occurs in countries around the Mediterranean Sea and is also important in Chile, California, and south Australia.

METABOLISM. Chemical changes in living cells, in which energy is provided for processes and activities and new materials are assimilated.

MICROCLIMATE. The local climate of a small site or habitat.

MIOMBO. A native name in deciduous woodland associations of *Julbernardia* and *Brachystegia*. Characteristic of parts of East Africa.

MODEL. A description, diagram, or other representation used to help visualize, often in a simplified way, something that cannot be directly or fully observed (e.g., a model of an ecosystem).

MOIST-TEMPERATE CONIFER FOREST. A humid forest dominated by conifers. A rich understory of mosses and other moisture-loving plants is a feature of this kind of forest. The trees may be massive and the forest highly productive, as in the northwest United States.

MONITOR. To keep track of, through observations, specific measurements, etc., often in order to regulate or control.

MONSOON. A wind system that reverses directions two times a year. The term is commonly associated with the rains occurring during the summer monsoons in Southeast Asia.

MONSOON FOREST. An open, deciduous or partially deciduous forest of tropical regions that develops in areas with alternating seasons of heavy summer rainfall and a pronounced dry season characteristic of monsoon climates.

MONSOON HUMID EVERGREEN FOREST. A broadleaved, evergreen forest occurring in the more humid part of the monsoon region, with a short dry season.

MONTANE. A general term meaning living on or belonging to a mid-altitude level of a mountain.

MONTMORILLONITE. A soft clay mineral that is usually white, grayish, pale red, or blue and consists of a hydrous aluminum silicate with considerable capacity for exchanging part of the aluminum for magnesium, alkalies, and other bases.

MULTIDISCIPLINARY EFFORTS. The efforts of two or more specialized disciplines combined for a common purpose.

MULTIPLE-USE OBJECTIVES. In regard to land, refers to the specific objectives that would take into account the various purposes for which the land could be used.

MULTIPLE USE (RANGE). The use of range for more than one purpose, e.g., grazing of livestock, wildlife production, recreation, watershed, and timber production.

N

NET PRIMARY PRODUCTION. The net plant biomass produced in a specified area and time interval.

NICHE. A site or habitat supplying the factors characteristically necessary for the successful existence of a particular plant or animal species, variety, or breed. Also, the role of particular plants or animals in an ecological community, especially their way of life (e.g., nitrogen fixation by legumes), and its effect on other plants, animals, and abiotic factors.

NOMADIC. Of, relating to, or characteristic or suggestive of nomads or their way of life.

NOMADS. Pastoral people who move their livestock frequently in search of suitable grazing. These movements are often cyclic or rotational, but may also be influenced by scattered rainfall and current forage growth.

NUTRITIONAL ENVIRONMENT. The character of the available feed supply — its given quantity, quality, distribution, and suitability for given animal species.

O

OPEN FORESTS. Relatively widely separated trees, i.e., with open canopy.

OPEN WOODLANDS. A parkland type of vegetation in which trees are clumped or grouped to form patches, often with a closed canopy, with grassland between tree patches.

OVERGRAZING. An intensity or a duration of use leading to deterioration of the range.

OVERSTOCKING. Placing a number of animals on a given area that would result in overgrazing by the end of the planned grazing period.

P

PAMPAS. Level, grass-covered (originally), treeless plains of South America, principally in Argentina, a large proportion of which are now cultivated due to excellent soils and favorable rainfall.

PARASITE. An organism that lives in or on a living host organism from which it secures part or all of its nutrients.

PASTORALIST. An owner of livestock who cares for his stock and depends on them for his livelihood. Applied most consistently to subsistence livestock people in Africa, but also applicable in the sense of ranchers in the United States and station-holders in Australia.

PASTORALISM. Social organization based upon stock raising and herding as the primary economic activity.

PATERNALISM. As used in this publication, refers to the principles or practices of a government that undertakes to supply needs or regulate conduct of the governed in matters affecting them as individuals as well as in their relations to the state and to each other.

PERCOLATION. Refers to the movement of water through the soil.

PERENNIAL PLANT. A plant that renews its growth seasonally for an indefinite number of years.

PHENOTYPE. The visible properties of an organism that are produced by the interaction of its genetic makeup and the environment.

PHOTOSYNTHETIC TISSUE. Leaves and other green plant parts that actively fix solar energy (manufacture carbohydrates).

PHYSIOGRAPHY. The natural features (shapes and geography) of the earth's surface.

PHYSIOLOGICAL. Of, or relating to, the functions and activities (rather than the form and structure) of living plants and animals and of the physical and chemical phenomena involved.

PRESCRIBED BURNING. The use of fire under control for specified purposes, such as to improve growth conditions for some species by lowering competition from other species.

PRIMARY PRODUCTION. On rangelands — amount (biomass) of range vegetation produced during a specific time, usually 1 year.

PRODUCTION SYSTEMS. Systems organized to achieve a certain type of product to meet particular needs, e.g., dairy-production systems or sheep-production systems. May also refer to the dominant characteristic of how resource-management objectives are achieved, e.g., nomadic grazing, cow-calf operation, etc.

Q

QUICK-AND-DIRTY FIELD SURVEYS. Surveys designed to quickly identify key or priority elements in problem analysis, project orientation, etc., without statistical sampling and other refinements for a high degree of precision.

R

RADIATION. The emission of energy, as through solar radiation.

RANGE CONDITION TREND. The direction of change in range quality as measured mainly by the composition of the vegetation, litter cover, and soil.

RANGELANDS. Lands on which the native vegetation is predominantly grass, grass-like plants, forbs, or shrubs suitable for grazing or browsing. Includes natural grasslands, savannas, shrublands, most deserts, tundra, alpine communities, coastal marshes, and wet meadows, as well as revegetated lands managed like native range.

RANGELAND INTERVENTION. An action taken to improve the condition or productivity of, or to otherwise change or modify the current practices relative to, rangelands.

RANGE MANAGEMENT. The science and art of planning and directing rangeland use to obtain an optimal mix of goods and services on a sustained basis.

RANGE-PRODUCTION SYSTEM. Overall and interrelated practices that are designed, or have evolved, to meet perceived human needs within prevailing biologic, abiotic, and cultural environments.

REMOTE SENSING. Most commonly refers to photography from an aircraft or satellite.

RENEWABLE RESOURCES. Any resource that can be replaced, such as forests, grasslands, and animals.

RESOURCE ASSESSMENT (RANGELANDS). Taking stock of the characteristics and distribution of the components of rangelands and evaluating them, as a whole and indivdually, usually for the purpose of more effectively planning their use.

RESOURCE-USE SYSTEM. In the case of rangelands, this refers to the procedures and methods for using the rangeland resources. These may vary greatly, the most advanced being integrated resource-use systems designed to achieve a rational and simultaneous use of the various existing range resources.

RESPIRATORY SURFACES. Refers to the surfaces of the tongue, mouth, and nose where water is lost through evaporation, an important means of heat loss for some animals.

RIVERINE. Living or situated on the banks of a river or other stream.

ROOT CROWN. The part of the plant between roots and stems.

RUMINANT. An even-toed ungulate with a rumen; lacks upper incisor teeth and chews the cud.

S

SAHARAN. Of, relating to, or characteristic of the Sahara desert.

SAHELIAN ZONE (THE SAHEL). A belt of land extending from east to west between the southern boundary of the Sahara and the northern part of the Sudanian Zone (approximately 16°N) with highly variable rainfall, frequent droughts, and sparse vegetation.

SAVANNA. A grassland with scattered trees occurring as individuals or clumps; essentially a transition type between true grassland and forest.

SHRUB. A relatively low, woody, perennial plant that generally produces several basal shoots instead of a single trunk.

SHRUBLANDS. Lands on which shrubs are the dominant vegetation.

SLASH-AND-BURN (SWIDDEN) AGRICULTURE. Synonymous with shifting cultivation.

SOCIABILITY (PLANTS). Refers to the spacing among individual plants — single, grouped, in patches, etc. Varies with species, reproductive modes, soil, and other environmental influences.

SOCIALLY SOUND. Acceptable and constructive to the population concerned.

SOCIOECONOMIC ENVIRONMENT. The combination of social and economic factors existing within a specific environment, including, for example, the level of employment, income, social organization, infrastructure, etc.

SOLAR ENERGY. Energy transmited by the sun (i.e., solar radiation), which drives the process of photosynthesis, provides heat, creates air movement, etc.

SPECIES. A category of taxonomic biological classification that ranks below genus, comprising related organisms capable of interbreeding.

SPP. Abbreviation for the plural of species.

STEPPES. Arid lands characterized by drought-tolerant vegetation that cover extensive areas with extreme temperatures.

SUBSISTENCE. Involving production of one's own minimum maintenance needs, with very little use of money; subsistence farming, subsistence economy, etc.

SUBSTRATE. The base or substance upon which an organism is growing or attached.

SUCCESSION. The natural replacement of plant and animal species and communities by others, e.g., the return of forest after cultivation is discontinued.

SUCCULENT THICKETS. Tangled, irregular vegetation that is dominated by shrubs or trees with conspicuously fleshy stems or leaves.

SUDANIAN ZONE. An east-west belt of land between the Sahelian and Guinean Zones (approximately between 8°N and 16°N) with rainfall between 500 mm and 1500 mm falling during the summer. Vegetation is mainly coarse grasses and small trees.

T

TECHNOLOGY. Methods and means that facilitate the application of scientific knowledge toward achieving a practical purpose; applied science. Has also been defined as a box of tools, including intellectual tools, that man makes and uses.

THORN SHRUBS. Shrubs with thorns and(or) spines.

TOPOGRAPHY. The surface configuration of the land — mountains, valleys, plains, etc.

TRAGEDY OF THE COMMONS. A point of view that contends that the main reason why grazing management is inadequate in many developing countries is the practice of communal grazing. It is thought that the individual pastoralist feels little responsibility for the range because, while he owns the livestock, they graze on land that belongs to the community as a whole. He therefore would be motivated to get as large a share of the forage as possible by increasing his animal numbers. The pastoralist is seen to be caught up in a self-destructive web, and therein lies the tragedy of the commons.

TRANSHUMANCE. The seasonal and regular movement of people and grazing livestock, typically from some form of permanent, generally lowland, location during the wet season, toward higher elevations, or otherwise more favorable areas during the dry season.

TRANSPIRATION. The emission of water vapor from leaf surfaces through openings known as stomata.

TYPE (VEGETATION). An association of plants presenting a characteristic appearance. The appearance is determined by the dominant or most conspicuous species (e.g., a coniferous forest type, a tall-grass prairie type, a sagebrush type, etc.).

U

UNDERSTORY. Plants growing beneath the canopy of other plants. Usually refers to grasses, forbs, and low shrubs under trees or brush.

UNGULATES. Hoofed mammals.

V

VAPOR PRESSURE (OF THE EVAPORATION SURFACE). An important indicator of cooling through evaporation from skin or leaf surfaces — particularly relevant in the tropics. It represents the pressure that would be exerted by a vapor in equilibrium with a liquid surface.

VERTICAL LAYERING. Strata of plants with different lifeforms occurring in the same area, e.g., trees, shrubs, herbaceous layers.

W

WATER-INFILTRATION RATES. Rates at which water will enter the soil — varying with soil structure and texture, degree of compaction, live plant and litter cover, etc.

WATERSHED. The area of land draining to a stream or other defined point.

WEEDS. Any plants growing where unwanted, but especially plants that interfere with the growing of cultivated or other economic crops.

WILDLIFE. Undomesticated animals considered collectively.

WILDLIFE CROPPING. The systematic, controlled harvesting of wildlife.

WILDLIFE RESERVES. Areas in which all, or particular species of, wildlife are protected either continuously or during a particular time of the year.

Author Biographies

R. Dennis Child is a range scientist who for the past 14 years has had experience with range ecology, range/livestock research, range forage resources, production-system modeling and natural resource planning. He began his career as a faculty member at Colorado State University, where he taught courses in range and natural resource management and became adept at developing computer range-planning procedures. Before becoming a coordinator with Colorado State's regional resources analysis program, Dr. Child spent 2 years as the program's computer programmer. For the past 8 years he has served as a range scientist for Winrock International. He is presently the project manager for the range management program in Kenya, where he spent 3 years from 1980 to 1983 as the project's range ecologist. On the project, he led studies to determine the use and limitation of rangeland plants under different grazing-management strategies and served as deputy chief-of-party his last year there. Other international experience has included training-project studies in Mexico, a tropical-grassland course in Costa Rica, and a review team mission to study the rangeland resources of the Hashamite Kingdom in Jordan. As project leader for the southern-forest-range-and-pasture program, he conducted regional surveys of forage resources. Dr. Child is experienced in the fields of agroforestry and farming systems and has worked with evaluations of diets of goats grazing upland hardwood sites.

Harold F. Heady is the noted author of the range management text books, *Rangeland Management* and *Range and Wildlife Management in the Tropics*. In addition he has authored 140 other publications in the fields of range management and grassland ecology. He received his Ph.D. in plant ecology from the University of Nebraska. In 1984 he retired from the University of California in Berkeley, after serving as a distinguished professor of range management since 1951. From 1977 to 1980 he was the assistant vice-president for agricultural and university services and associate director of the agricultural experiment station. From 1974 to 1977 he was the associate dean of the college of natural resources. Dr. Heady has had extended range management consultancies with the Food and Agriculture Organization of the United Nations in Saudi Arabia and in Malawi. He has had short-term consultant assignments on range management problems with the University of Nairobi, Bureau of Land Management, U.S. Forest Service, Department of State, and the governments of Australia, Israel, Kenya, Kuwait, Malawi, Mali, Mexico, New Zealand, Rhodesia, South Africa, Tanzania, Uganda, and Saudi Arabia. Dr. Heady has been an invited speaker to many international symposiums including ones held in East Africa, Mali, Chile, Mexico, and South Africa. He is a charter and life member of the Society for Range Management.

Wayne C. Hickey has a broad range of fields of expertise: animal husbandry, range management, beef production, arid land reclamation, land treatment practices, reseeding, land evaluation, methodology, study design, and field training of technical personnel. His practical range management background began in Texas and New Mexico where he was reared on working cattle ranches. He later was a self-employed range manager and operator. For 26 years he worked with either the U.S. Forest Service (USFS), Agency for International Development (AID), or the Food and Agricultural Organization (FAO) of the United Nations. He spent two years in Argentina preparing a soil and vegetation map of the semiarid and arid zones in preparation for land reclamation. Mr. Hickey later conducted a field evaluation study of 350,000 square miles of savannah belt in the Sudan. He also conducted feasibility studies in Nicaragua and El Salvador and is currently on a 2-year assignment in Lesotho. His varied experience in range management includes 36 years in the Southwest where he was involved in 1) ecological analyses of semiarid and arid rangelands for present productivity and future potential; 2) animal husbandry; and 3) improvement and(or) reclamation of depleted ranges. For 15 years Mr. Hickey instructed new range personnel with the USFS as well as wrote illustrated reports and instructional materials on range conditions. He received his M.S. degree in range management and botany from the University of California, Berkeley, and speaks Spanish fluently.

Roald A. Peterson is an internationally known range ecologist with broad experience in pasture and fodder crops, livestock production, soils, and plant genetic resources. He began his career by working for 8 years in range research for the U.S. Forest Service. The next 7 years he spent as a pasture specialist in Montevideo, Uruguay, where he organized, directed, and taught international courses on pasture and range management and livestock production. From 1961 to 1979 Dr. Peterson worked for the Food and Agriculture Organization: from 1961 to 1970, as chief of the pasture and fodder crops branch in Rome, he directed as many as 75 technical assistance field activities in diverse countries and helped develop an international program on plant genetic resources; from 1970 to 1974, as chief of the crop and grassland production service, he directed programs on pasture and fodder crops, fruits, and vegetables, field crops, industrial crops, and seeds; from 1974 to 1979, as manager of a livestock development project in the Dominican Republic, he emphasized an integrated research program on pastures and livestock that was influential in the establishment of a national center for livestock research, a goat experiment station, and a center for criollo cattle. As a consultant for FAO, he served on a program-planning mission in Somalia and for UNICEF in Mongolia. Dr. Peterson received his Ph.D. from the University of Minnesota in plant ecology, speaks Spanish fluently, and understands Portuguese, Italian, and Norwegian.

Rex D. Pieper received his Ph.D. in plant ecology from the University of California, Berkeley. For the last 20 years he has served on the faculty of New Mexico State teaching a broad range of subjects: range analysis (18 years), introduction to forestry (12 years), range plants (3 years), and advanced range ecology (4 years). Since 1966 he has been the advisor to all of the foreign undergraduate students studying range science, with approximately 20 students each year. In his capacity as a professor he prepared the syllabus, "Measurement Techniques for Shrubby and Herbaceous Vegetation" published for the range analysis class. For 4 years Dr. Pieper taught a 9-week course for international students on range management and forage production. He has been the project leader for numerous rangeland studies that included protected ranges, wooded rangelands, desert grassland ecosystems, ecology, and control of pinyon-juniper forestlands. He has received both distinguished teaching and research awards and has been an invited lecturer in Australia, Mexico, and Brazil. For 5 years he has been on the editorial board of the *Journal of Range Management*. Numerous large corporations have used his expertise as a consultant in the field of vegetational analysis and grazing evaluations.

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