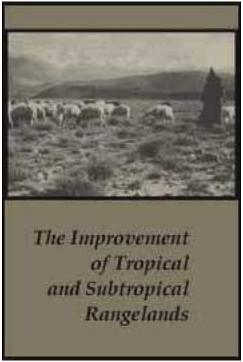
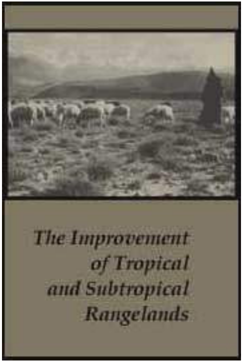


The Improvement of Tropical and Subtropical Rangelands (BOSTID)


The Improvement
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international development

Board on Science and Technology for International Development Office of International Affairs National Research Council

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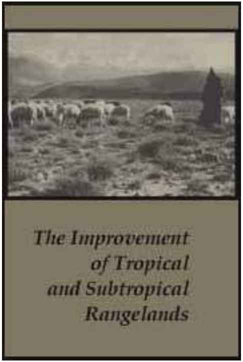

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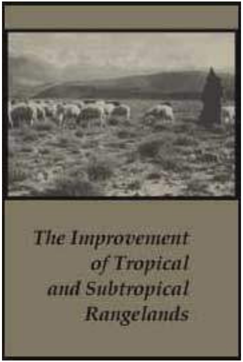
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Acknowledgements

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the

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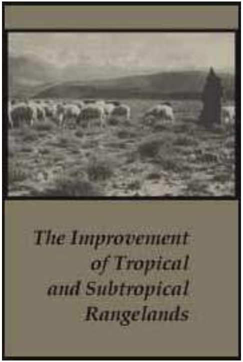

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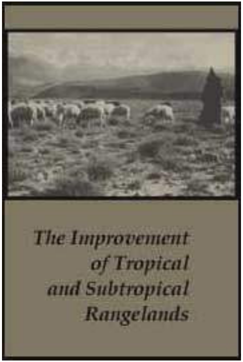

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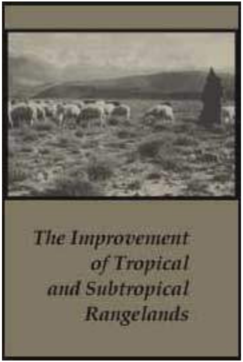

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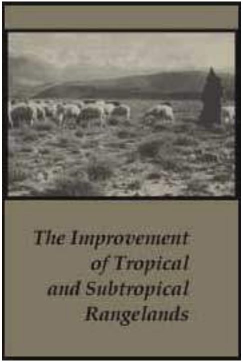


Preface

Overgrazing, fuelwood collection, uncontrolled burning, the unregulated exploitation of forest products, the growth of transportation networks, agricultural expansion into marginal areas, major social and economic changes are but some of the factors that have contributed to the degradation of tropical and subtropical rangelands. Periodic drought has intensified the impact of vegetation loss, and it appears that this loss may, in turn, prolong drought. Because rangelands comprise a substantial percentage of the earth's surface and support millions of human beings, it is critical to understand the complex causes of this cycle of drought and degradation, and to ensure that socially, economically, and scientifically appropriate measures be formulated and implemented to stem degradation and increase the productivity of rangelands.

The areas affected include some of the most vulnerable ecosystems in the world. For example, once disturbed, dryland ecosystems often require decades, or even centuries, to regain productivity. Nevertheless, there can be no moratorium on the use of such "fragile" lands; their products are vitally important. Although this report focuses upon problems of range improvement in Africa and

Asia, many of the observations and recommendations could be applied to the tropics and subtropics of Latin America as well.

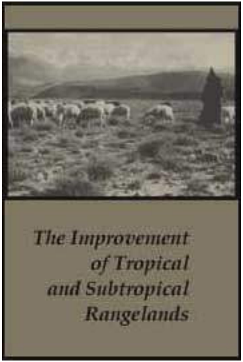
The panelists and other individuals responsible for preparing this report have no illusions regarding the case with which productivity can be restored to the world's rangelands. The areas are vast, and measures that could improve them are characteristically costly in terms of labor or capital. Rehabilitation efforts are further affected by social and political considerations.

This report takes a broad perspective. It focuses on the principles of range management by describing various indigenous adaptations to specific Old World ecosystems, and by discussing how experience elsewhere can complement indigenous knowledge. It also outlines techniques for assessing the condition of rangeland vegetation. Although the report to some extent draws upon North American experience, its authors fully acknowledge the limitations of this experience in addressing degradation problems in the tropics and subtropics. Nevertheless, this experience can usefully illustrate the application of basic principles, which the panel hopes will stimulate local research. What is needed is a basic appreciation of indigenous adaptations, a knowledge of local socioeconomic and environmental change over time, and innovation solidly based on an understanding of ecological principles.

Rangelands that are "common property" are particularly difficult to manage because of the frequent breakdown of organizations and institutions responsible for their welfare. Successfully managed rangelands characteristically benefit from some form of local control Therefore, case studies that describe successful approaches are also provided.

This report complements More Water for Arid Lands, published by the National Academy of Sciences in 1974, which describes littleknown, but promising, small-scale technologies for the use and conservation of scarce water supplies in arid areas. The Improvement of Tropical and Subtropical Rangelands is the third report to appear in the series Resource Management for Arid and

Semiarid Regions. Other titles include Environmental Change in the West African Sahel and Agroforestry in the West African Sahel.



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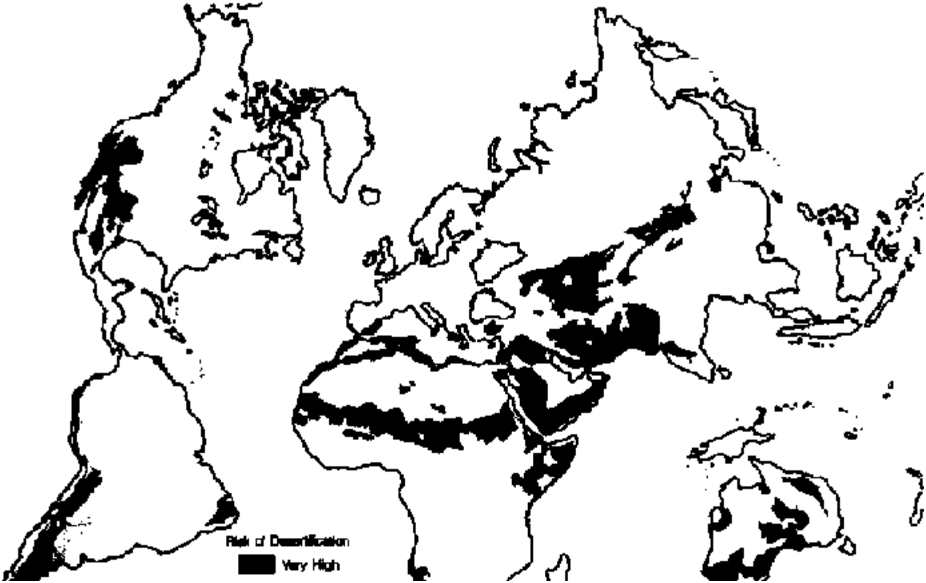
The Improvement of Tropical and Subtropical Rangelands (BOSTID)

Overview: Dimensions of a worldwide environmental crisis

The geographical scope

Rangelands are one of the most important land use types in the world. Roughly 47 percent of the earth's land surface is rangeland, about 80 percent of which is at least moderately degraded. Substantially more than half of this area lies in tropical and subtropical areas. By contrast, less than 10 percent of the earth's surface is devoted to arable agriculture. In recent years, degradation has been increasing, and many of the world's major rangelands are at risk. The desertification hazards map, compiled by several United Nations agencies, shows are as that are at greatest risk of desertification because of a continuation of factors such as low rainfall, terrain, soil and vegetation conditions, and high human and animal use. Identifying ways to arrest and reverse these trends is the central concern of this study.

Tropical and subtropical rangeland is usually characterized by rainfall so low or irregular that crop production is difficult unless irrigation systems, which require high capital investment, can be established. Typical vegetation types include grasslands, low-density forests (such as dry tropical thorn forests), and shrublands. The term desert is commonly applied to those rangelands that are the most arid and least productive of vegetation.



Areas at risk of desertification

Rangelands are used to support grazing of browsing livestock. The openrange system of livestock production is characteristically associated with the extensive use of sparse, scattered, and often seasonal or ephemeral natural vegetation. Most of the world's estimated 3 billion head of domesticated livestock are reared on tropical or subtropical rangelands, rather than on highly productive pastures or in feedlots. Most of the red meat consumed by humans is produced on rangelands. Some 135 million people, about 20 percent of the world's population, base their economies and societies on rangeland resources.

The pastoralists' systems of livestock production characteristically require movement of herds and herders over large areas, on either a seasonal basis (transhumant pastoralism) or a basis of perpetual migration (nomadic pastoralism). Pastoral socioeconomic systems can be further distinguished by combinations of other activities with those of herding. Herding, along with some agricultural crop production is a frequent combination, creating what are known as agro-pastoral systems; herding and tree-crop production creates silvo-pastoralism. Important economic activities of other pastoralists involve conducting, supporting, or controlling long-distance overland trade routes.

Reduced vegetative cover is often the result of overstocking, uncontrolled or concentrated grazing, removing woody plants for fuel or shelter, and clearing natural vegetation. Destructive management practices are often related to colonial-period modifications of indigenous management systems: for example, highly regulated land-use systems, such as the herima system of Masina, were widely converted to open-access systems with the imposition of the European law of public domain; the ecological integrity of indigenous pastoral systems was frequently destroyed through the imposition of international boundaries; cattle-based livestock systems were promoted in marginal drylands at the expense of sustainable indigenous systems based on better-adapted forms of livestock; wells projects encouraged concentrated grazing around water supplies; and the new economic order stimulated herd increase and its attendant economic rewards. Population growth in pastoral societies, approximately 1.5-2.0 percent annually (National Research Council, 1983b), is regulated by the observance of restrictive mores and other mechanisms. Hence, internally generated population growth is seldom a problem in pastoral zones. Indeed, declining population, with a corresponding inability to manage large herds, is often a serious problem. Further, the higher annual rates of growth in agricultural societies, characteristically on the order of 2.5-3.0 percent, encourages agricultural expansion into rangelands and forces pastoralists to increase use pressure on the remaining land base. Risks are highest in the more arid rangelands where rainfall is lowest, or least dependable, and where evaporation and transpiration rates are highest.

Soil erosion is another consequence of rangeland mismanagement.

Generally, it is a natural and continuous process, but in undisturbed ecosystems with a protective cover of plants, the soil is usually regenerated at the same rate that it is lost. If soil and vegetative cover are not in balance, erosion is accelerated. Under natural conditions, it takes several hundred years to generate a few millimeters of topsoil, but it can be lost to erosion in minutes if no protective vegetation is present.

Rehabilitating rangelands requires a respite from their intensive use. This involves the elaboration of a program of land management or, as a last resort, a program of land preparation, seeding, and planting, followed by careful management of use by livestock. To bring about such a program, alternative supplies of water, fuel, food, and other services may have to be provided to local pastoralists while the improvement is taking place. It is often helpful to develop programs of range improvement with reference to precolonial indigenous adaptations, where applicable, and knowledge of the changes that have occurred in local systems of production through time. Employing local people in seeding and planting efforts must also be a part of the development program. Local people must participate fully in demonstration projects; their understanding and commitment is clearly necessary for success.

Protection of a large number of relatively small rangeland areas is especially valuable to reveal what species are present, to provide for seed production, and to demonstrate the potential for ecological recovery. Demonstrating benefits that can be obtained by restoring the full natural cover and productivity of the vegetation may be a means of persuading local people that relaxing pressure on grazing lands is essential. However, this alone does not mean that long-term viability will be established. Protected areas and other conservation measures may restrict access to fuel, food, forage, and other products. If substitutes are not provided to compensate for the loss of these resources, the local community is likely to frustrate the conservation measures. Compensatory measures might include improving pasture quality, establishing fuelwood or animal fodder plantations, or providing credit, alternative food, supplemental animal feed, fuel, or fiber, as appropriate. If the measures concerned take time to yield results, they must be supplemented by measures that bring immediate benefits. For example, if a protected area or watershed forest is threatened by wood-cutting for fuel, it will be necessary to provide an alternative source of fuel that can be used immediately.

AN IGNORED RESOURCE

Dry grazing lands are largely ignored by governments and technical assistance agencies. Very little agricultural research funding goes to rangeland development. This stems partly from the limited political power of pastoralists or typical rangeland populations, and partly from the high cost of traditional land rehabilitation practices.

As a consequence of this neglect, opportunities have been lost to make vast marginal areas more productive for pastoral people and other rural populations. Further, deteriorating rangelands contribute to flooding; when precipitation interception and infiltration are reduced, runoff correspondingly increases. The problem is compounded by the downstream effects of flooding, variously including damage to crops and settlements. Insufficient research is aimed at finding ways to protect existing rangeland or identifying appropriate new crops that would complement livestock production. Agronomists the world over are taught the principles of agricultural land management, but are unfamiliar with special rangeland techniques. The uninformed conversion of rangeland to cropland has helped destroy rangelands. For example, the moldboard plow destroys the surface vegetation and exposes thin, dry soil to erosion by wind and water. Clearly, abuse of rangelands has accelerated erosion, at times rapidly, at times slowly. As soil erodes, sediments enter water courses and river bottoms, estuaries, and deltas, which have become the sink for nutrient-laden sediments.

CAUSES OF ENVIRONMENTAL DEGRADATION

The causes of land degradation must be understood in developing a strategy for land rehabilitation. Before costly methods are applied to promote range improvement, existing degradation forces should be identified and countered. Although the role of specific social forces is frequently unclear, devegetation - the progressive disappearance of plants from the land - is generally the result of human activities: overexploitation by man and his animals.

Degradation can begin with the depauperization of woodlands adjacent to and within dry rangelands, the encroachment of agriculture, or drought. Improper grazing usually follows these events on constrained range resources. Continued high animal density accelerates the removal of palatable species and the lack of competition permits the growth of species that are less palatable or less capable of supporting livestock on a sustainable basis. In many areas of the tropics and subtropics, the pressure of heavy use has caused ecological deflections from predominantly perennial grasses to annuals, resulting in a sharp reduction of late dry season carrying capacity. Woody shrubs, whose roots compete for soil moisture with the remaining grasses, also increase in number. In many instances, the woody vegetation is cut for fuel and shelter, thereby limiting the fodder contributions of the vegetation. Wind and water assault the exposed soil, causing cyclical flooding and erosion, eventually leaving the land to become bare and sandy. The overuse of vegetation by man and his livestock reduces the possibility of natural reseeding. The complex mixture of native species that are palatable or desirable becomes locally simplified as species become "extinct." In naturally semiarid regions, this leads to what is becoming known commonly as desertification - the simplification of the ecosystem to the point where its biological productivity and diversity are reduced to a minimum, and it can no longer sustain man and his animals in more than a casual, seasonal, and very limited fashion.

In areas such as the West African Sahel, there has been speculation that a progressive ecological downturn in productivity may be occurring in a highly variable climatic region that until recently experienced unusually favorable rainfall when viewed on an annual basis. However, the consensus of informed opinion is that to date there is insufficient evidence for attributing recent droughts to a major climatic change. These climatic cycles are very long term, and reconstruction of paleoclimate is difficult in the absence of historical records of rainfall fluctuation. Climatic cycles are perhaps 400-500 years long, with internal shorter cycles on the order of 70 years, and phases of 25-40 years (National Research Council, 1983b).

On the other hand, there is short-term evidence that the relationship between land abuse by man and his livestock, resulting in ecological deterioration, is more direct and irreversible than is generally appreciated. There is also evidence of low soil fertility, which continues to keep productivity low when combined with low rainfall (Breman and deWit, 1983). Historical review of former levels of vegetation, productivity, and land-use indicators shows that much higher levels of biological productivity were maintained throughout similar past fluctuations in rainfall, until changes in land-use patterns occurred (National Research Council, 1983b). One of the most significant changes was the introduction of large-scale cattle husbandry in colonial Africa, and the subsequent control of the tsetse fly in some are as by insecticides and by removing the vegetation of the fly's habitats.

In the areas where this occurred (sub-Saharan West Africa, the Horn of Africa, Botswana in southern Africa), a previously complex ecosystem comprising trees, shrubs, and grasses, with a wide variety of wildlife and livestock (camels, goats, sheep, and cattle), has become progressively simplified. The remaining perennial browse trees and shrubs and grasses are subject to overgrazing.

The consequences of devegetation are most stark in arid and semiarid areas, where they lead rapidly to erosion, elimination of many useful species, and a drastic drop in carrying capacity, resulting in death of animals and the drift of refugees to other areas. In wetter agricultural areas, environmental consequences may not be so dramatic, but the economic impact can be substantial because the erosion-droughtflood cycle interferes with cropping.

In recent years, an additional factor has been the rising cost of petroleum fuels, which has led to a growing use of fuelwood. Much of the fuelwood has been taken from areas surrounding agricultural regions for local domestic use. However, fuelwood and charcoal are increasingly being sold in towns to peripheral urban dwellers for cooking as well as to commercial establishments for various uses. Little of this additional demand has been met by increased planting of commercial or state fuelwood lots (National Research Council, 1983a). The impact of the deforestation is being felt as reduced moistureholding capacity and increased exposure of soil and crops to wind and rain cause lower yields of crops and loss of topsoil.

THE NEED FOR REHABILITATION

Rangelands are easy to destroy, but difficult to restore. However, because of their size and potential for increased productivity, their improvement can bring many benefits to developing countries. If left undisturbed, rangelands will, in most cases, regrow and reclothe themselves with vegetation, but it may take more than 50 years to return to a stable state. Opportunities should be seized that emphasize vegetation for useful forage and conservation of species.

Improving rangeland is generally a costly process because of low economic returns, relatively low productivity, fragility, site specificity, and often capricious precipitation. For privately owned land, it makes no sense to invest $50 to renovate a hectare of land worth $5. To halt the situation of dams, harbors, and rivers, and to slow the vast loss of topsoil and avoid threat of devastating flash floods, in most cases will require programs that encompass large areas and are supported both by the government and by the local community structure.

To overcome future starvation and malnutrition, either marginal lands must produce more food or there must be a decrease in the human populations relying on such lands. Revegetation is the critical key to the renovation of many rangelands. A cover of vegetation keeps the soil and water in place and decreases evaporation and runoff. Vegetation creates a living barrier to runoff and erosion by increasing percolation and soil storage of rainfall. It shelters the soil from scouring and provides a barrier that slows runoff. Its leaf litter absorbs water and protects the soil surface from rain and wind. Roots and soil organisms help break up the soil, making it porous so that water can infiltrate.

Revegetation is possible both by such natural processes as seed dispersal by wind, birds, and other animals, or carried by seasonal streams and floodwaters; planting by human activity, deliberate or unplanned also promotes new growth. Planned revegetation has two components: (1) direct intervention by seeding or planting trees, shrubs and grasses, using a variety of techniques; and (2) management interventions that serve to strengthen the role of natural revegetation processes.

Strengthening natural regenerative systems, in addition to direct planting methods, can be achieved in several ways. The basic objective is to add extra genetic material adapted to the ecosystem to provide a greater range of material for multipurpose use, and to assist the system to regain its former productivity and resiliency. For example, existing distribution mechanisms can be used, such as planting a mixture of perennial legumes around degraded well-heads, from which animals will spread them naturally (National Research Council, 1981). Nomadic pastoralists supplied with seed will be able to replant fodder shrubs and improve oasis systems with windbreaks or living fences composed of fodder legumes.

Where grazing pressure can be reduced and regenerative mechanisms strengthened, substantial regrowth is likely. The usual way of approaching this objective is to encourage herders to control their grazing. However, herders are usually more sensitive to the management of their grazing resources than are outsiders, and if overgrazing occurs, it is because other conditions make misuse of resources necessary for survival.

Animals can be used to upgrade rangelands if their use is carefully managed. Cattle, sheep, goats, and other livestock prefer somewhat different forages, so they can be grazed together or selectively in sequence. Grazing animals may encourage the dominance of unpalatable species depending on how grazing occurs. This selectivity is especially notable with some trees and shrubs. Improved grazing management may not eliminate these unpalatable species; therefore, other methods for removing them must be found.

Demands of the urban areas also generate pressures on rangelands. For example, many countries encourage the development of crop production in marginal areas to increase the amount of food available to feed a burgeoning urban population. Ways should be found to raise the efficiency of food and fodder production in areas where high productivity is possible, rather than expanding into marginal are as where crop productivity is low but grazing is more appropriate and dependable.

This report addresses issues of socioeconomic context, regional assessment and site evaluation, approaches to management, and criteria for plant selection in intensive rehabilitative efforts. The case studies provide further information regarding these issues, as well as descriptions of projects that have succeeded as a result of broadbased analysis and sensitivity to environmental and social context.

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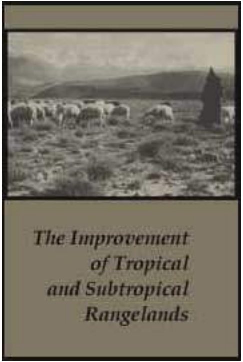
The Improvement
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The Improvement of Tropical and Subtropical Rangelands (BOSTID)

Part I

Introduction

In this report, rangelands are defined as "land carrying natural or semi-natural vegetation which provides a habitat suitable for herds of wild or domestic ungulates" (Pratt, Greenway, and Gwynne, 1966). Rangelands typically possess characteristics that make them unsuitable for agriculture or intensive forestry: they are variously too dry, too steep, too rocky, poorly drained, or too remote. In Africa, the Near East, and southern Asia - the geographical focus of this report - rangelands occupy 2,666 million hectares, or 53 percent of the land surface (table 1).

In the areas considered, there are two general systems of rangeland utilization: systems that use the land to produce goods that are removed or exported from the land (ranches), and those that chiefly provide subsistence for people associated with livestock and wildlife populations (indigenous pastoral systems). Contrary to popular belief in industrial nations, pastoral systems are not necessarily less productive than ranching systems. African pastoral systems, for example, are often as productive as market-oriented ranching systems in comparable areas in terms of protein produced per unit of land utilized.

	Area of Permanent Pasture[a] 1955	1975	1983 (million hectares)	Permanent Pasture as Percent of Land Area 1983	Open Forests[b] 1980 (million hectares)	Oth...
North America (United States and Canada)	277	265	265	14	275	
Europe	83	88	86	18	22	
USSR	124	374	373	17	137	
Central America (inclusive and Caribbean)	79	94	95	32	0.3	
South America	330	446	456	26	248	
Africa	615	785	778	26	508	1
Asia (except China)	279	372	359	21	61	
China	194	286	286	31	45	
Oceania	377	472	460	55	76	
World Total[e]	2,358	3,181	3,157	24	1,372	4

Notes:

a Includes permanent meadows and pastures and land that has been used for five years or more for the production of herbaceous

b Includes wooded land with a grass understory beneath the open canopy. Livestock and wildlife browse on both the leaves and tw

c "Other land" is a residual category defined by the United Nations Food and Agricultural Organization (FAO) in its *Production Yearb*
However, a significant percentage of this land may be grazed seasonally or in years of heavy rainfall. Half of this category is count

d Sum of areas of permanent pasture (1983), open forest (1980) and 50 percent of "other land" (1983)

e Numbers may not add up to totals because of rounding

Sources:

1 Data on "permanent pasture" and "other land" are from United Nations Food and Agriculture Organization (FAO), *1983 Productio*
FAO, *1955 Production Yearbook* (FAO, Rome, 1955)

2 Data on open forests and other wooded land are from United Nations Food and Agriculture Organization (FAO)/E... Co...
Rome, 1985)

Table 1 Distribution of the World's Pastures and Rangelands, 1955-

Most ranches are privately owned, and characteristically use investments of capital and various management techniques on large areas of land to increase livestock production. Unlike pastoral systems, labor inputs are low. Hence, ranching often produces more protein per hour of labor than does pastoralism. On the other hand, ranching requires vastly greater inputs of energy, and expenses incurred in connection with fencing, water development, brush control, revegetation, grazing management, and selective breeding are substantial.

Pastoral systems represent the principal form of rangeland utilization in Africa and Asia. They involve significant social adaptations to the movement of livestock or wildlife from one location to another in relation to the availability of forage and water. The rangelands utilized are seldom privately owned, and mechanical and chemical inputs are seldom prominent. The systems are labor intensive. It has been estimated that livestock and wildlife support some 30-40 million pastoralists, and the animals and animal products associated with pastoral systems are critical to millions of other individuals in settled communities (International Institute for Environment and Development and the World Resources Institute, 1987).

The importance of livestock in pastoral systems exceeds their value as sources of milk, meat, blood, and hides. Livestock often represent a means of accumulating capital and, in some societies, are associated with social status. They are assets that can reproduce and that can be liquidated should cash be required. In addition to supporting livestock, rangelands serve as sources of other significant economic products: bushmeat, fruits, berries, nuts, leaves, flowers, tubers, and other food for human populations, as well as medicinal plants, building materials, thatch, fencing, gums, tannin, incense, and other products important to the economies of rural populations (Sale, 1981; National Research Council, 1983; Malhotra, Khomne, and Gadgil, 1983).

The importance of rangelands as sources of bushmeat and vegetable foods for human populations deserves special attention. These foods are derived from species that are well adapted to the environmental peculiarities of the regions in which they are found. Hence, such foods are often available in the event of crop failure or substantial losses of livestock. Even during periods with average rainfall, satisfactory crop yields, and herd stability, such foods constituted a significant part of local diets. Indeed, in many societies, the offtake of wildlife from rangelands exceeds that of livestock in importance. In 1959, for example, the sedentary and pastoral peoples of the Senegal River Valley in West Africa relied upon fish and wildlife for over 85 percent of the meat that they consumed (Cremoux, 1963); native plants were of equal or greater importance. Since that time, widespread environmental degradation has dramatically reduced the availability of the natural products associated with local coping strategies and has correspondingly increased the vulnerability of rural populations (National Research Council, 1983). In most instances, the degradation is a result of breakdowns in the traditional resource management systems that for centuries had maintained an equilibrium between environmental systems and human activity (National Research Council, 1986).

Number of Cattle (in thousands)

Country	1940	1968-1970	1974	1978	1982	1985
Senegal	440	2,615	2,318	2,500	2,300	2,200
Mauritania	850	2,100	1,175	1,200	1,500	1,350
Mali	1,174	5,300	3,640	3,800	6,300	5,800
Burkina	431	2,900	2,300	2,600	2,871	2,800
Niger	754	4,200	2,200	2,850	3,487	3,530
Total	3,709	17,115	11,633	12,950	15,458	15,680

SOURCES. Gallais, 1979; Africa South of the Sahara 1986 1985; and Africa South of the Sahara 1988 1987.

TABLE 2 Cattle Populations in the West African Sahel

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Total	3,709	17,115	11,633	12,950	15,458	15,680

SOURCES: Gallais, 1979; Africa South of the Sahara 1986 1985; and Africa

South of the Sahara 1988 1987.

Rangeland ecosystems, particularly those in arid and semiarid regions, are highly susceptible to degradation. In many regions, degradation is chiefly a result of changing herd composition and overstocking. Particularly noteworthy since the advent of the colonial period has been a proportional shift in herd inventories favoring cattle, a form of livestock poorly adapted to dryland ecosystems, at the expense of well-adapted and less environmentally destructive forms, such as camels, as the former were more marketable within the context of the new economic order (Chassey, 1978). In the West African Sahel, for example, colonial policy resulted in an almost fivefold increase in cattle populations between 1940 and 1968 (table 2).

Agricultural expansion has also contributed to the degradation of tropical and subtropical rangelands. In drylands, agricultural expansion results in increased pressure on rangelands because the conversion of the more productive forage reserves to crop land forces pastoralists to "overgraze" the remaining land base (Thomas, 1980).

Moreover, grain crops deplete soil nutrients at a rate thirty times greater than the rate of nutrient loss in a properly stocked range ecosystem (Heady, 1975). The cost of replacing the lost phosphorus, potassium, nitrogen, and other nutrients is generally prohibitive.

In many regions, high levels of sustained use pressure have eliminated the more palatable plant species (species referred to as "decreasers" in range science). In dryland ecosystems, plant growth is relatively slow. When aerial biomass is consumed by foraging livestock, many plants respond by transferring nutrients from their roots in order to produce new leaves. This results in reduced rooting. Reduced rooting, in turn, reduces the ability of the plant to absorb moisture and nutrients even during rains. As the more palatable species are weakened, less palatable species ("increasers") become dominant. With continuing high levels of use pressure, increasers give way to undesirable shrubs, grasses, and forbs ("invaders"). As these species are overgrazed, the land surface is exposed to further, more severe, degradation. In the drylands of Africa and Asia, cattle have been particularly destructive. Unlike camels and goats and most native herbivores, which are predominantly browsers, cattle are grazers. Cattle therefore increase pressure upon perennial grasses and often eliminate them, causing ecological deflections toward ephemeral annual grasses and relatively unproductive trees and shrubs, such as Calotropis procera (Gaston and Dulieu, 1976).

The reduction or elimination of vegetative cover, in combination with trampling and the compaction of the surface by livestock, reduces infiltration and permits the mobilization of soil particles subject to transport by overland flow. This results in depressed groundwater tables and increased soil erosion. Surface exposure and the reduced organic content of soils also result in altered soil-water relationships and greater amplitude in soil temperatures. This altered soil ecology adversely affects important soil microorganisms, such as the rhizobial bacteria responsible for nitrogen fixation in acacias and other leguminous genera. This, in turn, affects nutrient regimes and results in a further loss of soil structure. Altered soil ecology directly eliminates additional plant species and frustrates regenerative processes in others. Further losses occur through disruptions in various biological dependency and affinity relationships. Environmental degradation both reduces range carrying capacity for livestock and affects wildlife populations through habitat modification. Rangeland conditions in selected countries of Africa, Asia, and Western Asia are described in tables 3, 4, and 5.

Location	Range Condition	Causes or Consequences
Cameroon		
Countrywide 8,300,000 hectares	Original perennial grassland and acacia types mostly replaced by annuals and unpalatable shrubs	Many years of heavy gra burning; drought in 197 degraded areas unlikely protection
Northern Sector 7 million hectares		
Sudano-Sahel region (acacia grasslands and steppes--Sahel; dry and moist woodlands--Sudanian types)	Almost denuded state in many areas	
Guinea-Congo region (south of Garoua)	Range in better condition than Sudano-Sahelian types	Use of range resources li fly infestations; pressure grazing lands can be par with tsetse control progr prophylaxis
Southern Sector		
Adamaoua Plateau and other localized areas About 1,300,000 hectares	Quality of range generally better than in northern sector	Rainfall higher, tsetse li probably stable; cattle i 1-2%/year expected to c

Table 3 Rangelands Conditions in Selected African Countries

Sudan 56 million hectares (permanent pasture), 24 million hectares (grasslands)	Range deteriorating and desertification accelerating, apparently continuing downward trend; 75-80 million total hectares suitable for agriculture but only 24 million hectares currently grazed, 7 million farmed	Increase of 5-18 million during last 30 years; c[illegible] marginal lands; woodcu[illegible] uprooting for fuelwood
Somalia 29 million hectares	Overgrazed perennial grasses replaced by annuals and in some cases unpalatable shrubs; deterioration accelerating. The rangeland is the greatest natural resource of the country.	Overgrazing; increased and livestock products
Kenya Rendille management area 13.249 square kilometers	3.9% range and 7.6% woodland are good-excellent; 77% and 70% are fair; predominance of fair and poor condition indicates a serious state of rangeland degradation	The cause for the degra[illegible] not certain; it is projec[illegible] significant improvemen[illegible]

Table 3 Rangelands Conditions in Selected African Countries - continue 1

Location	Range Condition	Causes or Consequences
Uganda 5 million hectares		
Northeast region Entire Karamoja District 816,300 hectares	Perennial grasses replaced by plants with lower nutrient requirements and less value to animals; irreversible erosion	Majority of grazing land area; livestock populatio rapidly; overgrazing (fee trampling)
Most of Acholi District Semiarid range	Reduction of ground cover Majority of grassland areas are four disclimax created by fire and grazing (would return to dry forest if these factors were eliminated)	
Morocco 12,141,000 hectares rangelands countrywide	Reduced forage production Expanding desertification	Overstocking; expandin agriculture; uprooting of increase soil erosion; dec grassland area
Tunisia 3,142,000 hectares	Degraded Rangelands estimated to be producing at 1/2 of potential (optimistic estimate);	Uncontrolled grazing; fu long history of misuse; sl estimated to be 3-8 time

	presumed to continue deteriorating	ideal

Table 3 Rangelands Conditions in Selected African Countries - continue 2

Zambia		
Countrywide, Upper Zambezi (Western Province), Kafue River locality Eastern Province 35 million hectares	Deteriorated; severe cover depletion; excessive stocking rates	Overgrazing--average st entire country is 0.32-0. hectare/livestock unit (than recommended)--n problem by rural inhabi erosion widespread
Zimbabwe		
Tribal Trust Lands 16,161,000 hectares	Approximately 50% in very poor condition (1960 survey); deteriorating	Overgrazing from increa population (+119% 196 deteriorated forage reso
Buffalo Ranch Farm 20,000 hectares		Stocking rate managem
--Cattle Section 12,000 hectares	Good condition; apparently stable, possibly improving	8.5 hectares/livestock u
--Game Section 8,000 hectares	Fair condition; apparently stable	8.0 hectares/livestock u (455 kg)

SOURCE: Adapted from World Resources Institute and the International Institute for Environment and I p 76.

Table 3 Rangelands Conditions in Selected African Countries - continue 3

Location	Range Condition	Causes or Consequenc
Syria		
Countrywide, 8,700,000 hectares (grasslands)	Overgrazed; trend either generally downward or stable at minimal productivity	Too many animals; mo rangelands destroyed l uprooting of shrubs fo establishment of wate without any grazing c
Interior Steppes: arid deserts	Originial plant community virtually eradicated; replaced by species of little interest to humans or animals; long history of degradation	Overgrazing, especiall development of wells p of plant resources

Table 4 Rangeland Conditions in Selected Western Asian Countries

People's Democratic Republic of Yemen		
Countrywide, 9 million hectares (grassland), 2,500,000 hectares (scrub forest)	Degraded stage of retrogression; declining, or stable at minimal productivity	Grazing pressure; fuelwood collectic

Yemen Arab Republic		
7 million hectares (pasture) 1,600,000 hectares (woodland)	Majority of "woodland" better classified as "rangeland"; depleted plant cover; severe sheet and gully erosion, decline in livestock numbers	Long history of degradation; overgr fuelwood cutting; World Bank belie range can be restored to some exter
Iraq		
Countrywide, 36,040,000 hectares (grazing land, i.e., uncultivated) 100,000 hectares (forage)	Low productivity; progressively downward trends	Uncontrolled grazing; conversion of desert lands to dryland farming
Steppe Zone, 6,200,000 hectares	Predominance of unpalatable shrubs; disappearance of natural vegetation; historical downward trend; continuing loss of rangeland	Overgrazing, conversion to dryland
Mountain Range (forest and sub-alpine)	Palatable perennial grasses generally scarce; annuals predominate	Long history of overgrazing
Alpine Meadows	Good seasonal grazing (four months); apparently stable	Limited seasonal usage
Southwest Desert, 16,700,000 hectares	Apparently fair--but steady deterioration	Overgrazing, in past due to transhu flocks from neighboring countries

Table 4 Rangeland Conditions in Selected Western Asian Countries - continue 1

Location	Range Condition	Causes or Consequences
Oman		
1 million hectares (permanent pasture), 20,208,000 hectares (other land)		
Desert and Mountain	1975 little evidence of damage to plant communities; stable, perhaps improving	Herd size decreasing in n
Sain Katat and Batinah	Overused	Excessive woodcutting; l trampling by livestock
Settled Areas	Perhaps fair condition at present, possibly improving	Animals are concentrate but heavy reliance on fo
Jordan		
6,316,253 hectares (grazing and/or uncultivated)	Loss of vegetation; degradation for hundreds of years, but utilization has become increasingly destructive in the past few decades; substantially increasing erosion with pavement-like soil	Overstocking, especially affects reforestation) Lack of water more limit feedstuffs; sedentarizatic animals in smaller areas periods, human populati sixfold over 55 years, inc for red meat; long-term, degradation

Table 4 Rangeland Conditions in Selected Western Asian Countries - continue 2

Saudi Arabia		
Countrywide 85 million hectares (pastureland) Arabian Shield-South 2,400,000 hectares, (9.5% of total country area)	Increase in biomass production since 1967 but species composition indicates degraded forage resource; poor, 40%, fair, 20%, good-excellent, 40%; human-caused destruction of rangeland has increased significantly	Widespread availability transport of animals and areas previously used in production units increas 1967; rangelands are los for sheep (grazing) and camel and goat (woody
Iran		
Countrywide, 1,100,000 hectares (specified as pastureland)	Severe depletion of range; (disappearance of most preferred perennial species, e.g., Artemisia and Aristida) and continuing deterioration; serious soil erosion and flash runoffs	Heavy overstocking--es carrying capacity by 4 t gathering, widespread e dryland cultivation into grazing areas; climatic f

SOURCE: Adapted from International Institute for Environment and Development and World Resources I p. 68.

Table 4 Rangeland Conditions in Selected Western Asian Countries - continue 3

Location*	Range Condition	Causes or Consequences

India 11,850,000 hectares	Highly degraded; overgrazed; soil erosion and desertification, reduction in grazing land/animal ratio; gradual conversion of forests to savannahs and steppes	Overstocking of sheep and goats; agriculture expanded into margina government neglect; no manageme fodder production or rangelands
Sri Lanka 439,000 hectares	Native grasses of low grazing value; area not reported to be degraded; gradual increase in livestock numbers	Grazing areas frequently affected b cyclones, heavy rains, and overflow water tanks; religious objections li range animal production
Nepal 1,978,000 hectares Rangelands are concentrated in mountainous areas	Degraded; overgrazed; soil erosion on steep slopes; deforestation	Excess unproductive livestock; clo Tibetan border to livestock from N causes overgrazing
Pakistan 5 million hectares Rangelands are concentrated in Baluchistan	Poor; most rangelands estimated to produce 10-15% of potential; the "former acacia savanna" of the Indus Valley alluvial plain is the important grazing area; dry; overgrazed; most areas completely devastated; entire species of edible plants eliminated, valley floors completely devastated; other areas, dry and heavily used; soil erosion; desertification;	Overstocking, estimated at three t the ideal; heavy nomadic use; fuelv demand by city dwellers

extensive damage to vegetation cover

Table 5 Rangeland conditions in selected Asian countries

Afghanistan 30 million hectares	Low mountains of the Hindukush north slope are good summer pasture; southern desert is good winter range; other areas are heavily overgrazed; the heavily grazed southeastern foothills of high mountains of Hazaradiat still have fair to good grazing; many rangelands have seriously declined, and this is continuing	Uncontrolled stocki major migration rou gathering; steady ex cultivation
People's Republic of China 285,690,000 hectares	41% of total land used for grazing; 25% of grasslands deteriorated; erosion is "dangerously accelerated"; loss of productivity; desertification	Population pressure tion attributed to o ment heavily favore rangelands during t remaining thin fore into cultivated field
North China	Too arid; unproductive; poor grazing land; heavily overgrazed; badly eroded; low forage production; poor forage [illegible]	Removal of best gr and urban develop on remaining range [illegible]

	quality, soil erosion by wind and water; plant cover deterioration faster than rehabilitation	...ive grassland are ... management of gra...
South China	Poor pasture quality; restricted seasonal grazing time, low carrying capacity and poor cattle growth	

*Note: Size of Rangeland: Figures are those given by the United Nations Food and Agriculture Org... Permanent Pasture, which underestimates total size of rangeland

SOURCE: Adapted from International Institute for Environment and Development and World Resour... 1988-89, p 80.

Table 5 Rangeland conditions in selected Asian countries - continue 1

The effects of rangeland degradation often extend well beyond the rangelands themselves. Dust originating in degraded rangelands is transported by dry-season winds to distant areas, causing annoyance, health hazards, and costly interruptions in air and ground traffic. The rapid release of runoff in degraded rangelands following rains contributes greatly to destructive flooding in downstream lowlands, and sediment entering drainage systems in degraded rangelands shortens the useful life of reservoirs and irrigation systems.

Less obvious effects would include the impact of rangeland devegetation on climatic regimes. For example, it is now widely believed that precipitation is strongly influenced by biogeophysical feedback mechanisms (Charney, 1975). According to this hypothesis, drought is reinforced through changes in vegetative cover. Large-scale losses of vegetation would increase surface albedo, which, in turn, would affect the atmospheric energy budget in such a way that the subsidence, which promotes aridity, would be intensified.

Further, it is now believed that levels of precipitation are strongly influenced by soil moisture locally released into the atmosphere through evapotranspiration. Hence, reduced vegetative cover and decreased soil moisture would result in reduced local precipitation. Finally, losses of vegetation affect surface roughness in the atmospheric boundary layer. Surface roughness contributes to the destabilization of moisture-laden air masses, thus encouraging precipitation. Devegetation also reduces carbon dioxide uptake in the planetary biomass. The greater concentration of carbon dioxide in the atmosphere contributes to global warming, causing changes in atmospheric circulation and rising sea levels through the melting of continental ice sheets (Study of Man's Impact on Climate, 1971; Woodwell, 1984).

The science of range management originated in North America, and North American approaches to range management are described in several wellknown volumes, such as A. W. Sampson (1952), Stoddart and Smith (1955), R. R. Humphrey (1962), and National Research Council (1962, 1984). Historically, attempts to transfer experience gained in the management of North American or Europe an rangelands to the management of tropical and subtropical rangelands have been unsuccessful (Heady and Heady, 1982). In improving tropical and subtropical rangelands, it is important to carefully characterize the physical system being managed in order to better understand the biological potential of the system and assure that critical ecological processes are restored and maintained. It is equally important to relate efforts in range improvement to the needs,

knowledge, adaptations, and capabilities of local populations, as well as to the broader economic and political contexts of such efforts. The widespread belief that pastoral systems are simply artifacts of the past requires reexamination. The view that range improvement in the tropics and subtropics should focus narrowly upon the increased per unit productivity of selected forms of livestock, usually cattle, at the expense of the biological diversity basic to the maintenance of local coping strategies and economies should similarly be reexamined. This report describes tropical and subtropical rangelands, addresses issues of socioeconomic context, discusses approaches to regional assessment and site evaluation, explores management strategies, and provides criteria for plant selection in relation to efforts in range improvement. The case studies appended to the report provide further information regarding these issues. The Improvement of Tropical and Subtropical Rangelands is the third report to appear in the series, "Resource Management for Arid and Semiarid Regions." Other titles include Environmental Change in the West African Sahel (1983) and Agroforestry in the West African Sahel (1983).

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The nature of tropical and subtropical rangelands

This report focuses on areas of low and undependable precipitation within the tropics and subtropics. (1) Much of the area is occupied by savannahs and thorn-bushlands, often characterized by a rich diversity of grasses. The prominence of grasses in tropical rangelands in many instances reflects the repeated use of fire in hunting or range renewal (Sauer, 1952), as well as the coevolution of grasses and wild herbivores (Harris, 1969). Substantial tracts of forest are associated with tropical rangelands in some regions; in others, extensive swamps created by the seasonal overbank flooding of exotic rivers are features of considerable regional importance.

Tropical rangelands differ greatly from rangelands in temperate regions, and social adaptations to these differences are reflected in the management of range resources. Differences of climate (Trewartha, 1954), soils (Sanchez, 1975), vegetation (Davy, 1938; French, 1957), and other environmental factors are well documented and generally well understood. The management of tropical rangelands is further affected by the prevalence of livestock diseases. Rinderpest, foot-and-mouth disease, contagious bovine pleuro-pneumonia, anthrax, east-coast fever, trypanosomiasis, and sheep pox have historically taken heavy tolls in the tropics (Pratt and Gwynne, 1977). Strategies to blunt the impact of disease include increasing livestock holdings to levels that assure the survival of a breeding nucleus. The relatively high levels of social, economic, and political differentiation within the tropics similarly affect the exploitation and management of range resources.

Range classification

Range management issues are usefully considered within the context of ecoclimatic zones. In this report, these zones are defined largely on the basis of land potential and moisture availability (Pratt and Gwynne, 1977). Within the tropics, five such zones can be distinguished:

1. Humid to dry subhumid (moisture index not less than -10).(2) This zone is characterized by forest and derived grasslands and bushlands, with or without natural glades. The grestest potential is for forestry (perhaps combined with wildlife and tourism), or intensive agriculture. The natural grasslands of this zone require intensive management for optimum production. Approximately 0.8 hectare is required per livestock unit, depending upon the related grassland association. (3) In this zone, approximately 2.5 livestock units are required to support one subsistence pastoralist; hence, 2 hectares are required to support each individual. The maximum population density per km² is about 50 pastoralists (see table 1-1).
2. Dry subhumid to semiarid (moisture index -10 to -80). The vegetation of this zone includes moist woodland, bushland, and savanna. Forestry potential is low. However, the agricultural potential is relatively high, soils and topography permitting, with

emphasis on lea farming. Large areas are generally under range use and, with intensive management, can carry 1 livestock unit per 1.6 hectares. Approximately 3 livestock units are required to support 1 subsistence pastoralist. Thus, 4.8 hectares are required to support 1 individual. The maximum density of pastoralists would be approximately 21 per km^2. Regular burning is an important management tool in this zone.

3. Semiarid (moisture index -30 to -42). These are areas with marginal agricultural potential, which in some regions is limited to rapidly maturing grains. The natural vegetation is characteristically dry woodland and savanna. This is potentially productive rangeland. Approximately 3.5 hectares are required per livestock unit, except where dry seasons exceed 6 months. The corresponding human carrying capability is 7 individuals per km^2. Animal husbandry is limited principally by the encroachment of woody vegetation and, in some locations, by leached soils. In many areas, particularly in Africa, the more open country with a high density of wildlife is a valuable tourist attraction.

	Ecoclimatic Zones				
	1	2	3	4	5
Hectares required per livestock unit	0.8	1.6	4.0	12.0	42.0
Livestock units required to support one head of population	2.5	3.0	3.5	4.0	4.5
Hectares required per head of population	2.0	4.0	14.8	48.0	189.0
Maximum population density per km^{2a}	50.0	21.0	7.0	2.0	0.5

[a]These figures presume that all land is accessible and productive; if actual population density under subsistence pastoralism even approaches these estimates, overpopulation is indicated. Higher population can only be sustained if the pastoralists derive a substantial part of their subsistence from vegetable foods--collected, grown, or procured in exchange for livestock.

TABLE 1-1 Relationship between Ecological Zone, Livestock Carrying Capacity, and Maximum Population Density under

Subsistence Pastoralism

TABLE 1-1 Relationship between Ecological Zone, Livestock Carrying Capacity, and Maximum Population Density under Subsistence Pastoralism

	Ecoclimatic Zones				
	1	**2**	**3**	**4**	**6**
Hectares required per livestock unit	0.8	1.6	4.0	12.0	42.0
Livestock units required to support one head of population	2.6	3.0	3.6	4.0	4.6
Hectares required per head of population	2.0	4.0	14.8	48.0	189.0
Maximum population density per km^2 [a]	60.0	21.0	7.0	2.0	0.6

[a] These figures presume that all land is accessible and productive;

if actual population density under subsistence pastoralism even approaches these estimates, overpopulation is indicated. Higher population can only be sustained if the pastoralists derive a substantial part of their subsistence from vegetable foods--collected, grown, or procured in exchange for livestock.

SOURCE: Modified after Pratt, 1968.

4. Arid (moisture index -42 to -51). This zone is suitable for agriculture only where fertile soils coincide with a favorable distribution of precipitation, or where rainwater is concentrated in depressions. Many arid rangelands are dominated by species of Acacia or Prosopis. Perennial grasses, such as Cenchrus ciliaris, can be prominent, but succumb quickly to inadequate management. As many as 12 hectares may be required per livestock unit. Wildlife is important, particularly where dry thorn-bushland predominates. Burning requires caution but can be highly effective in range manipulation. Approximately 4 livestock units are required to support 1 subsistence pastoralist, and the maximum population

density per km^2 is 2 individuals.
5. Very arid (moisture index -51 to -57). This zone supports rangeland with relatively low potential. The characteristic vegetation is shrub or grass steppe, with trees largely confined to water courses and seasonally inundated depressions. Perennial grasses, once dominant in many areas, are now localized within a predominantly annual grassland. Growth is confined largely to the seasonal flushes characteristic of summer therophyte vegetative communities, and grazing systems are generally based on pastoralism. Populations of both wild and domesticated animals are restricted by temperature, forage, and available moisture (Schmidt-Nielsen, 1964).

Systems of range classification should be regionally adjusted to include descriptions of the existing vegetation in physiognomic terms, with subdivisions by species composition.

Social system-ecosystem interactions

Most environmental systems are highly modified by human activity. Hence, an understanding of the biological and use potential of these systems benefits greatly from analyses of environmental change over time (National Research Council, 1981). Such analysis is also important in defining ecosystems and in identifying cause-effect relationships that have contributed to changes in the composition and productivity of these systems.

Indigenous social systems, through selection and adaptation, are functionally associated with local ecosystems through flows of energy, material, and information (4) (Rambo and Sajise, 1984). Changes in either the social or environmental system result in changes in the other. Hence, each system must be thoroughly understood if positive change is to be realized. In many, perhaps most, instances, highly disruptive changes are responses to external stimuli. Many examples could be cited. For example, the highly regulated land-use systems of many societies (see the discussion of the hema system in case study 9, Part II) were commonly transformed into open-access systems through the imposition of European public-domain law often combined with land expropriation, a situation that, in many regions, has led to intense use pressure and severe environmental degradation. Similarly, colonial era introductions of cattle into inappropriate areas (such as Zone 5 of the above classificatory system) has led to severe degradation and zonal compression (National Research Council, 1983b). The fixing of boundaries, at national and sub-national levels, has reduced or eliminated strategies of mobility that are crucial to these areas. In addition, increasing market integration has converted highly conservative systems of land use into opportunistic systems that impose greater pressure on available resources. In some cases, this has destroyed the subsistence base that supported the coping strategies of local populations, and has reduced the range of economic options available to them. Wildlife, honey and beeswax, gums and resins, cordage, tannin, and medicinals are among the economic products lost through the de gradation of environmental systems in Africa and Asia.

Characteristically more subtle, but equally important, impacts on socioeconomic and environmental systems result from destructive modifications of indigenous systems of values, ideology, knowledge, and social organization. An unfortunate consequence of past efforts in international development is that so much attention was directed toward the transformation of what are now belatedly recognized to be critically important social adaptations, without corresponding effort being made to understand the context or consequences of the changes promoted.

In addressing issues of range management in the tropics and subtropics, many of the most important clues as to appropriate actions for governments and development agencies reside in the analysis of traditional adaptations to local environmental systems. Growing awareness of the importance of traditional adaptations is contributing to a shift of emphasis by governments and development agencies from open-field cultivation and plantation forestry to more biologically complex agroforestry or agro-sylvo-pastoral systems (National Research Council, 1983a). The growing interest in camel husbandry in the drylands of Africa and Asia similarly reflects pre-colonial strategies of rangeland utilization. In West Africa, for example, camel-based livestock systems were commonly replaced by cattlebased systems by colonial administrators unfamiliar with the characteristics of the drylands of West Africa in relation to the requirements of cattle. By so doing, these administrators contributed greatly to the current environ mental emergency in Africa (National Research Council, 1983a). An overview of selected African and Asian pastoral adaptations is contained in Douglas Johnson's The Nature of Nomadism (1969).

NOTES

1. In this report, the terms "tropics" and “tropical” are expanded to include the subtropics (Tropical and Subtropical Steppe, Tropical and Subtropical Desert, Mediterranean or Dry Summer Subtropical, and Humid Subtropical climatic regions) as well.
2. Moisture indexes provide expressions of climate derived from monthly rainfafl and evaporation, with the estimate of evaporation based upon measures of radiation, temperature, saturation deficit,

and wind speed, weighted for altitude and latitude. They are calculated on the basis of Thornthwaite's concept of moisture indexes (1948), combined with Penman's estimate of evaporation (1948) .

3. In many areas of the tropics, a livestock unit is taken to be a mature zebu cow with calf at Soot (averaging about 300 kg liveweight and having a daily dry matter requirement of 6.5 to 8.5 kg).

4. In an ecological context, information is simply organized or patterned energy or material that tells the observer something about the past, present, or probable future state of an ecosystem or its components. Human response to environmental information is unique compared with that of other organisms because it occurs largely at the cognitive level where cultural conditioning affects both perception and the selection of appropriate responses.

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The social context for rangeland improvement

The loss of desirable vegetative cover is a threat to world food supplies, to the quality of human life, and to the environment. Desertification, erosion, and the loss of useful plant species can be arrested through revegetation. However, revegetation efforts have often ended in failure or have had limited impact. This has been particularly true in semiarid and marginal lands where the reestablishment of plants is a delicate process.

Revegetation often is required to correct the abuse of existing resources by people and their livestock. More often than not, the success or failure of revegetation schemes is also determined by human activities. Normally, adequate protection of an area is possible only if the people who use the land alter their behavior. If they are unwilling or unable to do so, revegetation efforts become more expensive or even impossible. Far too often, planners and conservationists ignore the human ecology of an area and fail to appreciate the importance of project lands for the survival of human populations. This chapter outlines the relationship between human activity and vegetative change.

In most instances, environmental degradation is a product of human activity. In the regions of Africa and Asia that are the focus of this study, overgrazing, the excessive cutting of fuelwood, and the cultivation of fragile lands - abuses often precipitated by the openaccess provisions of colonial public-domain law and subsequent lack of governmental management and control and economic differentiation associated with commercialization - have led to a loss of plant cover and required the development of government revegetation programs. To fully appreciate why this has occurred and how this process can be reversed, we must first understand how human beings have adapted to specific environmental settings.

Production systems in tropical and subtropical regions

The lands considered here are those in which permanent, sustainable crop production is not possible because of soil and climatic conditions. These regions have, however, supported substantial human populations for thousands of years. In these areas, people have developed production systems adapted to the low and variable productivity of these lands. In semiarid regions and marginal areas, one can find many kinds of production systems - hunting and gathering, agricultural, pastoral, and agro-pastoral systems. Pastoralism and agro-pastoralism are probably the most common production systems in these regions; this is because domestic animals can convert vegetation on land unsuitable for agriculture into food and fiber. In Asia and Africa, agro-pastoral and pastoral societies take many forms. The exact organization of these production systems is influenced by local environmental factors, by history, by culture, by economic considerations, and by level of technology. In addition to these differences, there are similarities that must be understood if successful revegetation is to take place. Traditionally, people who live in semiarid and marginal lands have relied on two strategies - diversification and mobility - to cope with the erratic and generally low productivity of their lands. Mobility is perhaps the most important characteristic of these production systems. By moving about, one can take advantage of the spatial and seasonal variation of plant production. In crop production, systems of shifting and opportunistic cultivation are examples of strategies based on mobility. Land is cultivated for several years, and then it is abandoned to fallow and new land is cleared. The shifting nature of cultivation permitted natural revegetation processes to occur - provided that the fallow cycle was long enough.

Livestock are particularly mobile. Not only can they move about to "harvest" sparse vegetation, but they convert grasses and shrubs into useful products. They also can harvest perennial shrubs and plants that are less susceptible to annual variations in weather than are annual food crops.

Livestock herds in semiarid and marginal regions are rarely confined to the same pastures year-round. Seasonal movement is a common feature of livestock production even among sedentary groups (figure 2-1). A noteworthy difference between agro-pastoralists and pastoralists is that the former do not often move as complete families with their herds, whereas family members often accompany herds among pastoralists. The movement of animals may be as little as a few kilometers or as much as hundreds of kilometers. Movement, however, permits herds to take advantage of seasonally rich pastures, helps to adjust to spatial variances in precipitation, and reduces the stress that is placed on vegetation through constant grazing and trampling (Wagner, 1983).

Mobility is probably the key production strategy for pastoral nomads. Strategies of mobility, such as nomadism and transhumance, are particularly prevalent in areas where the pattern of rainstorms is such that there can be wide differences between the amount of rain received by two plots a few kilometers apart (Gilles and Jamtgaard, 1981). Nomadism serves to reduce environmental stress and personal risk, but it is also more productive than settled livestock husbandry. In eastern Africa, in areas of Masai pastoralism, the grazing capacity of the land is increased 50 percent because of herd mobility (Western, 1982). In the important livestock-producing areas of Africa, comparisons of the productivity of mobile and sedentary herds have indicated the superiority of mobility. In Sudan, Haaland (1977) noted substantially higher mortality rates among sedentary herds than among mobile ones. Breman and de Wit (1983) studied the migratory system based in the Inland Delta of the Niger River in Mali, and found that its productivity often exceeds that of Australian and North American ranches.

Other studies in West Africa have indicated that a disproportionate number of sedentary cattle were lost in the 1968-1974 Sahelian drought. Losses of herds that quickly moved into rainier regions in response to the drought were minimal (Gallais, 1977; Sall, 1978). Not only were the impacts of drought less severe on mobile herds, but migrating herds caused less environmental degradation. Loss of vegetation around boreholes where herds permanently congregated was so severe that it could be easily recognized from satellite photos. Mobility is an important aspect of production systems in semiarid and marginal areas.

Mobility is just one way to cope with a harsh environment. Diversification of subsistence activities is another. For farmers, the ownership of livestock is one diversification strategy. Animals may survive even when grain yields are quite low, so livestock may represent a store of capital that can be used in years of drought. Farmers may also grow a number of different crops to reduce the risk of crop failure. Wheat and barley or maize and sorghum may be grown together because one species tolerates drought better than another. Diversification goes beyond the diversification of agricultural enterprises. Farmers may also have secondary occupations, engage in trade, or in migrant labor to reduce their dependency on a fickle pastoral environment. In traditional subsistence-oriented societies, this diversification lessened the dependence on the immediate environment and lessened the probability of ecological disaster.

At first glance, traditional pastoralists would appear to have been a highly specialized group dependent solely on livestock production, but in reality these societies were highly diversified. First, multiple species of animals were raised (figure 2-2). Camels, cattle, sheep, and goats all have different water requirements, feed preferences, and reproductive rates. Browsers - camels and goats - are less affected by annual fluctuations in rainfall and in grass production than cattle and sheep. Small stock such as sheep and goats have high reproduction rates when they are well nourished. They can thus be used to build up herds rapidly after droughts or to take advantage of two or three consecutive wet years. Not only did traditional pastoralists diversify their herds, but they also had other sources of livelihood. Pastoralists in the Sahara, Asia, and the Andes were often heavily involved in long distance caravan trade, in the mining of salt, and/or in military pursuits. Often they ruled or exacted tribute from sedentary groups, which provided them with agricultural products. As a result, pastoralists, like agro-pastoralists, developed diversified sources of livelihood to prevent over-reliance on any particular aspect of the environment. One consequence of this diversification was to reduce the impact of man on any single ecological niche.

Societies living in marginal areas have many institutions to facilitate diversification and mobility. One important institution is the land-tenure system. In general, the private ownership of land in such regions is rare, except in those places where irrigation or other conditions made permanent cultivation possible. Land ownership in these areas was, and still is to a large extent, collective. In areas of shifting cultivation, the cultivator had use rights to a piece of land as long as it was cultivated, but did not have an inalienable right to that land. Such rights belonged to a large group - a village, commune, clan, or tribe.

Rights to grazing lands and forest lands are also collective. However, in this case there are no user rights to individual pieces of land. Although an individual might habitually use a pasture or forest, mobility is essential to responding to fluctuations in precipitation and plant production, making exclusive assignments of land impractical. Often the boundaries between the territories of different pastoral groups are imprecisely defined, and relations of kinship and reciprocity exist that permit groups to temporarily use the pastures and forests of others. Collective ownership of pasture and forestlands is also more economical than individual tenure. The low and variable annual productivity of these lands makes the cost of maintaining fences and access roads to individual plots prohibitive. Under these conditions, if mobility is not impeded by private ownership of lands, all users of collective lands benefit from higher levels of production.

As the discussion above indicates, collective ownership of land facilitated both mobility and diversification. Therefore, a large proportion of range and forest lands remains today under the control of localities or as part of the public domain in Europe, Japan, and North America.

To say that lands are collectively owned does not imply completely open and unregulated access. That would lead to a "tragedy of the commons" situation such as that described by Hardin (1968), where individuals would each increase their herds or their use of the forests until the productive capacity of the resource was destroyed. Such unregulated exploitation of the environment ignores the fact that members of subsistence groups depend upon each other for their survival and are not individuals single-mindedly pursuing personal gain at all costs (Runge, 1981). Also, it is illogical to suggest that any group would stand by and let their subsistence base be destroyed.

The "tragedy" historically appears to occur where competition over land and its resources increases, and where differential access and market opportunities and political control reduce the effectiveness of prior regulatory procedures. Studies of traditional management systems indicate that in those areas where disease and warfare do not prevent overgrazing, a variety of institutions regulate the use of common resources. First, these lands are not open to all potential users, but are either used exclusively by certain groups, or at the very least, some groups are given priority over others. In the case of cropland, people usually need permission from local leaders or councils to use land. Even when access to pastures and woodland was technically open to all, controls over access to water, shelter, and minerals was controlled by localities or owned by individuals. For example, wells and springs are often "owned" by individuals or by small groups (Helland, 1982). Without access to water or to shelter, no one can use pastures, even if they are technically common resources.

Subsistence-oriented groups in semiarid lands do not necessarily live in harmony with nature. Pastoralists and agro-pastoralists often significantly alter the vegetation and fauna of the areas in which they live. Sometimes they do destroy the resources upon which they depend. If they do so, they quickly destroy their ability to survive and are either forced to move on or disappear. Direct dependency on the immediate environment for most subsistence needs is a strong incentive for the development of institutions to protect the environment. While most groups living in marginal areas have only rudimentary institutions, in some areas, such as southern Africa and the Atlas Mountains of Morocco, elaborate institutions evolved to regulate pasture use (Bourbouze, 1982; Gilles, 1982; and Odell, 1982). In recent years, many of the mechanisms that have traditionally served to protect vegetation have become less effective. The reasons for this decline are discussed below.

Context of environmental degradation

Typically, lands requiring revegetation have had their plant cover destroyed through improper farming methods, the extensive gathering of wood for fuel or construction purposes, or through overgrazing. In terms of destructive impact, cultivation and the gathering of woody species probably have had more impact on the environment than have grazing animals. Livestock are the primary cause of desertification only in areas where large numbers of grazing animals are concentrated, such as around boreholes. Overgrazing is, however, a major cause of vegetative change and often inhibits the restoration of plant cover.

Although these three actions of man are the main causes of environmental de gradation , the reasons for increased degradation are still debated. Four common reasons for environmental deterioration are climatic change, population growth, economic change, and human fallibility. Usually these factors interact. Over the past 30 years, the human and animal populations using semiarid and marginal lands have grown, thereby putting more pressure on the environment. Given the cycles of wet and drought years common to semiarid regions, such as the West African Sahel, this led to population growth that could only support the population in wet periods. The shortsightedness of governments and donor agencies also has contributed to environmental deterioration. In Africa in particular, ill-conceived water and livestock development projects contributed substantially to overgrazing (Bernus, 1971; Haaland, 1977). These factors have all contributed to the need for revegetation programs, but merely listing the mechanisms and factors leading to environmental problems does not explain the process by which this has occurred. Also, in many cases, destruction of plants in marginal areas has been occurring at a faster pace than have climatic or population changes. This has been due to factors that have reduced both the mobility and the diversity of traditional economies. These factors also undermined traditional mechanisms of environmental protection. The need for revegetation and conservation has been accelerated by the growth in government power, in modern economies, and in the use of improved technologies.

Changing political conditions have had severe impacts on many pastoral societies of Africa and Asia. In many cases, national boundaries were created in such a way that grazing lands used by one people were split between two or more nations. Over time, nations have incressingly restricted the movement of people and animals across frontiers . Such restrictions reduce the diversity of ecosystems available to herders and lead to herds spending longer periods of time in marginal areas than they had in the past. For example, it has been argued that the imposition of the frontier between Uganda and Kenya was the reason for overgrazing and the destruction of the pastoral economy of the Karamajong of Uganda (Quam, 1978). The imposition of national boundaries also had some impact on trading activities.

The growth of state authority has impinged on pastoral production systems in several other ways. To a large degree, governments have eliminated the raiding and warfare that often characterized the relationship between herders and their neighbors. While pacification is in itself quite desirable, it often had the effect of opening grazing lands to groups that previously did not have access to them. Often the state did not give title or the means to restrict access to grazing lands to anyone. This in effect made it impossible for communities to enforce local regulations designed to protect pastures or woodlands. Often government planners felt that local rules concerning pasture use prevented efficient meat production or impeded nation building (Sall, 1978; Cole, 1981). They wished to create a common pasture situation in which any individual who wished to raise livestock was free to do so, both to expand meat production and to combat tribalism. In many instances, these changes were accompanied by changes in herd composition. For example, cattle production increased dramatically in the northern Sahel at the expense of less destructive, better adapted forms of livestock, such as the camel (National Research Council, 1983).

The reduction of intergroup hostilities and the introduction of government land resource planning had additional impacts on the viability of traditional pastoral economies. Governments have generally sided with agriculturalists in disputes between them and pastoralists. The cessation of raiding by pastoral groups led to projects to expand agricultural production, and population pressures have contributed to the expansion of cultivated are as - further reducing the mobility of traditional pastoralists. Generally, those lands that are occupied by farmers are marginal croplands but are among the best watered and most productive pastures (figure 2-3). They are generally those used during the dry season or in winter months when the productivity of other pastures is low. The loss of these lands to farmers forces animals to remain longer on more marginal lands and increases the likelihood of erosion and desertification due to overgrazing. Even where arrangements can be made for the pasturing of animals on stubble, as is the case of much of West Africa, mobility is reduced. Such arrangements can often be developed for regular seasonal usage of pastures but not usually for occasional or for emergency use.

While governments frequently have reduced pastoral groups' land rights, in some countries there have been attempts to protect pastoralists by adjudicating land rights. French colonial authorities in North Africa attempted to adjudicate tribal boundaries, and, in East Africa, post-independence governments have attempted to delimit group ranches and grazing blocks. These attempts have in some cases restricted the growth of herds and have probably reduced overgrazing, but they also can restrict mobility if strictly enforced. As mentioned earlier, the fluid, often vague, boundaries between the areas used by different pastoral groups facilitated mobility. Overly rigid enforcement of these rules can confine animals to too small an area or, if not enforced, boundaries may be ignored. If local groups still manage resources, the fluidity of boundaries may not be a problem, but if reforms have eliminated or modified the ability to control grazing, then once again the creation of a common resource may be required where one previously did not exist.

The growth of market economies, and the adoption of new technologies that this growth permits, have also reduced the viability of tradition al resource management strategies . In a subsistence economy, one's survival is directly linked to the local environment. One exploits a wide variety of resources, but one's survival over time depends on the sustained productivity of the immediate environment. The introduction of a market economy changes this. First, one can specialize in animal production or in the cutting of fuelwood. To do so means that one can increase one's standard of living by intensely exploiting a particular environmental niche. If one is selling for cash, the feedback loop between subsistence levels and environmental conditions is less effective. If demand for one's product is rising, price increases can more than cover the loss of productivity because of overexploitation of the environment. For example, as a pasture deteriorate, a subsistence herder may only have milk and meat to eat, while a commercial beef producer may for a long time experience stable or even rising income levels.. Free labor markets also reduce the risk of degradation for the individual. The destruction of the land may cause hardship, but the possibility of wage labor in the city always exists.

In the past, some form of “passive" management occurred when quantities of stock died as a result of drought. Today, in many parts of Asia and North Africa, herders can maintain herd numbers, even when pastures and water are totally exhausted, by trucking water and feed to their animals until rains restore pastures. The purchase of feed and the delivery of water, often subsidized by governments during droughts, leads to levels of overgrazing that would be impossible for traditional subsistence pastoralists. An unintended consequence of improving veterinary services and reducing disease is to remove this “natural" regulator of herd size. Another consequence of the growth of the market economy is that individuals enjoy increased economic independence. In traditional groups, each individual family is dependent on others for survival. In such a setting, social pressure and the threat of ostracism may be sufficient to prevent deviant behavior. The development of a market economy increases economic differentiation and may reduce consensus on resource management questions.

Modernization has also contributed to the degradation of the environment in some areas Improved medical and veterinary techniques have reduced the constraints that disease placed on human and herd numbers. The development of roads and the introduction of motor transport have caused some nomads to become more dependent on herding as caravans have become less profitable and have probably encouraged the switch from camels to cattle. Roads and trucks have also made it profitable to cut fuelwood or produce charcoal at great distances from cities, and trucks make it possible to increase the use of remote or poorly watered pastures (Thalen, 1979). In many cases, mechanized plowing and sowing have made it profitable to plow up rangelands where rainfall is so erratic that only one year in three witnessed successful harvests. The introduction of new technologies often requires changes in traditional institutions, hence an unintended consequence may be a weakening of those institutions that have in the past protected the environment. In this light, publicly funded revegetation programs may be seen as attempts to correct some of the excesses of rapid social change.

As we can see, then, desertification and the destruction of plant cover have been caused by a number of factors. It is important to remember from these examples that environmental deterioration has been accelerated because the mechanisms that formerly helped people adapt to semiarid and marginal environments have been weakened. Diversification and mobility have been limited, and the feedback from man's use of the environment has been distorted. If revegetation efforts are to be successful, they must create a sustainable human ecology as well as stable, productive environmental systems. Too often, projects have undermined themselves by ignoring people, or by inadvertently accelerating the processes of declining diversity and mobility in production systems.

Successful revegetation requires changes in land use patterns so that the reestablishment of vegetation is encouraged. In the past, attempts have been made to control access to revegetated areas by changing land tenure arrangements. Nomads have been settled, private and group ranches have been created, and forest reserves have been legislated, all in attempts to control access to project lands by reducing animal movement and by restricting people to particular parcels of land. As previously mentioned, the reduction of mobility may threaten the viability of traditional subsistence systems. If their livelihood is threatened, people may resist overtly or may passively resist by bribing forest guards or by grazing or cutting revegetated areas when they are not being properly guarded. Conflict between traditional users at the very least raises the cost of revegetation substantially, and may in many instances negate project efforts.

In some cases, the failure to understand the importance of mobility can mean disaster even when project goals are attained. Boreholes are examples of efforts to increase available pastures that, in fact, led to local desertification and to heavy livestock losses during droughts (figure 2-4). At other times, the success of programs in one area may lead to larger levels of environmental deterioration outside a project are a . Herds that are required to leave the are a of a range or reforestation project must go somewhere, hence the revegetation projects may accelerate the processes that they are intended to reverse. The settlement of nomads may increase overgrazing, as we saw in the Sudanese example (Haaland, 1977). The creation of private ranches or group ranches may improve the conditions of ranges in their boundaries, as it has in some parts of Kenya (Hopcraft, 1981; and case study 10). If ranchers are not excluded from common pastures they may use their individual pastures as reserves, which permits them to exploit other lands more intensively (Little, 1983). In a similar vein, people may preemptively destroy an area rather than have it come under the control of a public range or forestry program. Pascon (1980) cites the example of herders in Morocco who, when presented with the successful establishment of wheat grass on overgrazed plain, chose to plow up the entire region and plant wheat rather than give up control of their resources to a range management scheme. These examples, though perhaps more graphic than most, are typical of many attempts at revegetation.

Those who plan revegetation efforts often face a dilemma. Successful programs may require the use of coercion and force, which, in turn, raises the cost of revegetation, reduces the extent of the area that can be treated, and reduces cooperation. This is one part of the dilemma - coercion reduces the program area. On the other hand, success in a limited area may be illusory; vegetation may be protected at the cost of widespread environmental destruction in adjacent areas. This is a cruel dilemma.

In part, this difficulty can be overcome if rehabilitation efforts are carefully reconciled with local systems of production. If one understands how a revegetation program will impact on an area, one may be able to make adjustments in other parts of the local production system to compensate for disturbances caused by a program. Instead of paying money for guards, it may be possible to plant highly valued, multiple-use species that would strengthen and diversify the local economy, thereby justifying protection by local populations. Approaches can be developed that enhance the advantages of mobility and diversity for production systems in these areas. The creation of new jobs or economic activities may have a greater impact on the environment than the creation of forest or grazing reserves.

Given sufficient time and money, it is possible for planners to characterize a production system and to design appropriate revegetation programs. An easier approach may be to reduce technical input, but to work closely with local populations to identify appropriate types of interventions and to monitor the program. Such an effort may succeed in areas where government policies have often undermined local institutions.

It is of particular importance that environmental rehabilitation projects yield multiple benefits. Multiple uses of vegetation should be encouraged. Local involvement should reduce management costs through increased self-enforcement of conservation rules. Finally, the project should help reestablish a local sustainable resource system that is not dependent on the vagaries of public funding and political will. There may often be some trade-offs between the efficiency of revegetation and local involvement. There may be more efficient and more effective ways of conserving and protecting plant cover than those acceptable to local populations. For example, the policies developed by ranchers and the Grazing Service in the United States under the Taylor Grazing Act did not satisfy many conservationists, but they could be implemented effectively and did lead to improved range conditions in the western United States (Foss, 1960; U.S. Forest Service, 1979). The goal of any revegetation program should be to create a viable environment for plants, animals, and people. This can be done only by placing revegetation efforts within the context of local and regional production systems.

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The economic context

The previous chapter dealt with the behavioral characteristics of groups of people living on, or using, arid and semiarid lands. This chapter focuses on the economic behavior of the individual or the individual household.

Economic analysis of pastoral management practices has proved difficult for several reasons. First, many analysts have a tendency to consider the household as one homogeneous decision-making unit, with the "head" of the household as the decision-making director. In fact, households are heterogeneous and not always clearly defined, and decision-making is generally delegated to a large number of individual household members who may not share the same interests. Surveys that used the (male) family head as the sampling or observation unit have therefore yielded incomplete or biased data, leading to biased conclusions.

Second, many studies have limited the focus of the analysis to one aspect of household activities - only land management or only animal performance, for example. These single-commodity approaches fail to incorporate interactions among various household enterprises. Therefore, the predictive value of the analysis for household behavior is low.

Third, any economic analysis is based upon the identification of determinants and their impact. Even when successful in identifying important factors, allocating values ("impact") to these factors has proved extremely difficult. In resource-poor environments such as arid rangelands, the assessment of values is highly time- and location specific. Not only do values vary over time and space, but also among individuals, households, tribes, and generations. The cost (negative value) of soil degradation will be felt more by future generations than by present ones (who might be causing the degradation).

Fourth, and related to the third point, is the difficulty in assessing the social costs and benefits (as opposed to the private values). Communal grazing is believed to occur with virtually no cost to the herders, but with possible social costs (in the case of overgrazing) to the society as a whole. In the same vein, the long-term costs are not necessarily the same as the short-term costs. This problem is aggravated by the fact that the life span of range management projects is generally limited to 10 years or less, even in projects that attempt to deal with long-term problems, such as desertification and erosion. Another example of social costs is the negative effect that a project might have on resources or persons outside the project are a . For example , the development of a pocket of highly productive rangeland for crop cultivation might have a negative impact on the usefulness of the surrounding low-quality rangeland because during a drought period cattle would not have access to a highly productive forage source (Sanford, 1983). Other social costs or benefits include the impact of interventions on employment and equity.

Finally, we cannot overlook the fact that many projects have failed for reasons other than inadequate economic analysis. For example, biological scientists and technicians have often provided projects with short-term, single-commodity technical input-output relationships that have contributed to illusionary expectations of possible changes in management behavior.

For some time, pastoralists have therefore been labeled "irrational," but this allegation has been refuted by a growing number of case studies. Cattle portfolio models developed in industrial countries have found useful applications in pastoral situations (Jarvis, 1980; Ariza-Nino and Shapiro, 1984), and elements of African and Asian range management systems are finding application in industrialized countries (National Research Council, 1984).

Range systems

A range system is the arrangement of soils, water, crops, livestock, labor, and other resources that the manager works according to personal preferences, capabilities, and available technologies. The major factors that influence productivity are determined by the characteristics and interactions of (1) the physical environment, (2) the economic environment, and (3) the social environment. Subsystems can be recognized within range systems. Interdependencies and interactions among resources (land, labor, crops, livestock, capital, water, wood), environment (climate, topography, soil, market), and humans (family members, relatives, friends, enemies) are essential components of the analysis.

The tools for the economic analysis of range systems are essentially the same as those for conventional farm management studies: budget analysis by gross margins or partial budgeting, linear programming, and discount procedures. However, when these methods are applied to a range system, the results have become more reliable, essentially because previously unidentified factors (inputs as well as outputs) are taken into account.

Little (1984), however, recommending the systems approach, also points to two major limitations: the assumption that the household is the proper unit of analysis, and the lack of focus on macro and micro linkages in problem solving. He therefore recommends a combination of household production and regional analysis.

Rangeland management systems have been divided into two major systems: nomadic and transhumant. Another distinction is based on land ownership - that is, pastoral nomadic, open-range ranching, and fenced ranching (Behke, 1984; Lawry et al., 1984). This distinction is addressed in a later section of this chapter.

Rangeland Farming Systems

Within the framework of range systems analysis, relatively little work has been done on livestock-related issues. Several reasons account for this neglect:

· Most of the research is done by crop-oriented agronomists and social scientists, neither of whom are familiar with livestock and therefore tend to overlook their role.

· Most of the livestock have multiple outputs (such as draft power, meat, milk, manure, hides, status) and non-cash inputs (especially for ruminants).

· A substantial part of these outputs is used within the household (for example, draft, manure), and therefore only indirectly contributes to the cash income of the pastoralist.

· The cash income from livestock activities often occurs at irregular intervals and on special occasions; it is easily if not intentionally overlooked during household surveys (Sabrani and Knipscheer, 1982). Even if scientists have explicitly focused on the livestock component of the range system, they have encountered a number of additional problems. Table 3-1 compares livestock-oriented farming systems research with crop-oriented farming systems. Factors such as genetic variability, differences in age and productivity, and problems with farmer cooperation, measurement of effects of input and output, and representativeness of prices have constrained the researcher in conducting on-farm trials (Amir et al., 1985). Consequently, rangeland research has proved to be time-consuming, logistically difficult, and expensive.

Major Features of Nomadic Systems

Nomadic systems are based on livestock, and the main source of income is derived from meat and animal by-products. Typical for nomadic systems is the annual migration of livestock and managers, for example, from highlands in the summer to plains in the winter, as in the arid and semiarid region of Asia. The influence of climate as well as culture is large, as families or tribes or both travel together, following the opportunities that the climate offers. In this kind of culture, crop farming is held in low regard. The crop component in nomadic production systems is virtually nonexistent. The linkages between livestock and other household activities are found in household processing (for example, wool and weaving) and fuel supply. Land use is characterized by grazing and collection of fuelwood, while the manure of the animals returns some of the nutrients to the soil. Although nomads generally are believed to be unconcerned with improvement of feed resources, it is also known that they are aware of the importance of future pasture availability and, therefore, are careful in their grazing practices (Camoens et al., 1985).

Major Features of Transhumant Systems

The critical difference between nomads and transhumants is the existence of a substantial crop-producing activity in the household system. Transhumants migrate seasonally with their flocks but have a permanent residence area. The crop enterprise is generally for subsistence, while the livestock component is geared for the market.

	Situation with respect to:		
Factor	Crops	Livestock	Implications
Mobility	Stationary	Mobile	Difficult to measure and

			control non-experimental factors
Life cycle	Generally less than 4 months	Generally over one year	Increases costs likelihood of losing experimental units
Life cycle	All units synchronised	Units seldom synchronised	Difficult to find comparable units
Multiple	Only grain and/or tuber and residue	Multiple ouputs, meat, hides, milk manure, power	Difficult to measure or evaluate treatment effect
Nonmarket	Few	Many	Difficult to evaluate input or outputs
Experimental unit size	Small divisible	Large nondivisible	Increases cost, risk to cooperate
Producer attitude towards product	Impersonal	Personal taboos	Difficult to cull, castrate
Management variability	Low	High	Difficult to isolate treatment

			effect
Observation units	Many	Few	Large statistical variability

TABLE 3-1 Comparison of Characteristics of Crops and Livestock and Implications for On-Farm Testing

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Nonmarket	Few	Many	Difficult to evaluate input or outputs
Experimental unit size	Small divisible	Large nondivisible	Increases cost risk to cooperate
Producer attitude	Impersonal taboos	Personal cull, castrate towards	Difficult to product
Management variability	Low	High	Difficult to isolate treatment effect
Observation units	Many	Few	Large statistical variability

SOURCE: Bernsten et al., 1983.

Climate and culture play dominant roles in transhumant systems, comparable to those of the nomadic systems. Because of the crop activities, some of the land is privately owned (or rented). Some of the large ruminants are used for draft purposes, but the application of manure provides a linkage between the livestock and the crop component of this farming system.

The common feature of both the nomadic and the transhumant farming systems is the mobility of the households. This strategy to meet the variability in the physical environment is associated with unstable control of resources, notably land and water, and difficulties of planning herd size and herd movements.

Ownership

The three types of land ownership are communal, modified communal, and exclusive (Lawry et al., 1984). Exclusive land tenure (private ownership or lease) has been seen by some as a solution to overgrazing. Overgrazing in turn is believed to find its economic rationale in the "tragedy of the commons": the individual herdsman has no economic incentive to reduce the number of animals as long as there is free access to communal land and water. Although assignment of grazing rights is advocated as a solution (Doran et al., 1974; Jarvis, 1980), experience has not yet shown that tenure reform is an effective policy instrument (Lawry et al., 1984, p. 247). One of the problems is that stock limitations specified in leases are almost never enforced. There is also growing evidence that pastoralists are very aware of the need for rangeland conservation and will act accordingly (National Research Council, 1986).

Narrowly related to the issue of land ownership is that of access to water. Because moisture is the overriding limiting factor in pastoral management, access to water is crucial. In many cases, control of water supply implies de facto control of land use. Water sources can be classified according to ownership in a similar way. Other classifications are made according to the technical operations (including boreholes, dams, wells) or size.

The basis of range economics

Economics may be defined as the science dealing with the allocation of scarce resources among various competing uses, with the objective of maximizing utility or maximizing satisfaction of human wants. For range projects, scarce resources include:

· Land. In the broadest sense, land includes all natural resources such as air, minerals, soils, natural vegetation, and water.
· Labor and management. These are the resources furnished directly by humans.
· Capital. This refers to the intermediate products (inputs) created from land, labor, and funds used in further production. Capital is both the money used to pay for inputs, and the buildings, machinery, livestock, and purchased inputs that can be valued in dollars or local currency.

Organizations must conscientiously attempt to guide the allocation of their physical, financial, and administrative resources among sectors and competing programs to further national objectives (figure 3-1). This is true whether the resources committed are being invested by the government directly or by individuals within the economy.

The concept of economic rationality is a central consideration of economic theory and the definition given above. A rational economic person, or consumer, is one who seeks to maximize utility or satisfaction. There is often a close identification between farmers' or pastoralists' consumption and their production decisions.

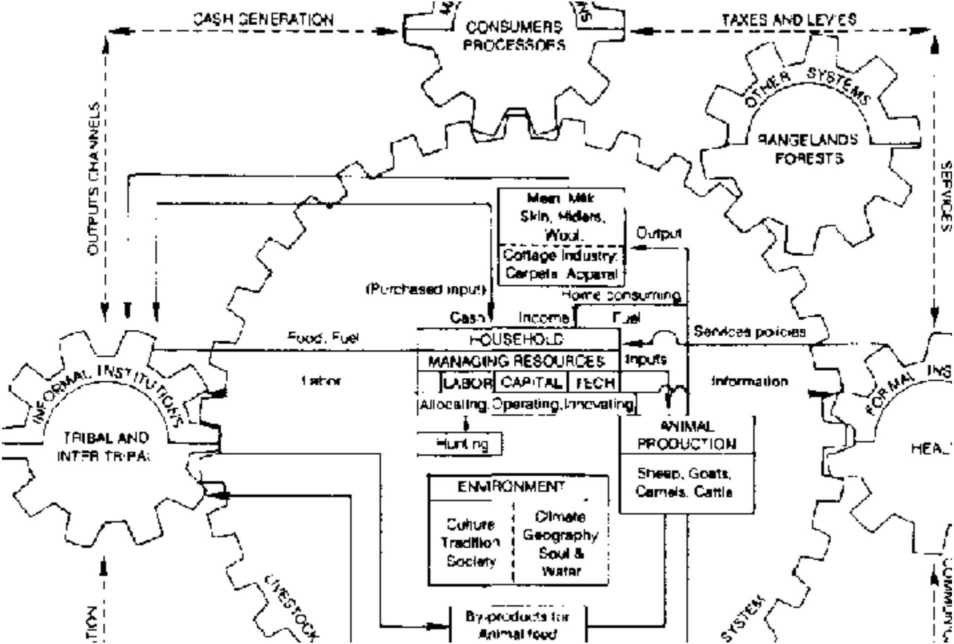
Personal preferences also affect decisions within the agricultural or natural resource development sphere. Some decisions may be made to enhance prestige or status with a peer group. Some may reflect consumption rather than production expenditures.

As mentioned previously, however, nonrational behavior may be difficult to judge, in particular by those outside the culture. What seems nonrational to an urban dweller from the industrilized world may be quite rational when examined in the correct cultural context. Therefore, in determining proper economic behavior, what outsiders consider maximum utility may not be in the best long-term interest of pastoralists. Clearly, before a rational economic strategy can be formulated, the culture and traditional economic behavior must be understood.

Project analysis

Agricultural or natural resource developments might best be defined, explained, analyzed, and understood as “projects.” Projected cash flows over a period of time are required for comparisons among alternative development projects or other investment decisions.

In defining a project, Gittinger (1982) said:


CASH GENERATION
CONSUMERS PROCESSORS
TAXES AND LEVIES
OTHER SYSTEMS
RANGELANDS FORESTS
OUTPUTS CHANNELS
SERVICES
Meat, Milk
Skin, Hides,
Wool.
Cottage Industry:
Carpets, Apparel
Output
(Purchased input)
Home consuming
Cash
Income
Fuel
Food, Fuel
HOUSEHOLD
MANAGING RESOURCES
Services policies
Inputs
Labor
LABOR
CAPITAL
TECH
Information
Allocating, Operating, Innovating
INFORMAL INSTITUTIONS
TRIBAL AND
ANIMAL PRODUCTION
Sheep, Goats,
Camels, Cattle
Hunting
ENVIRONMENT
Culture
Tradition
Society
Climate
Geography
Soil &
Water
By-products for
Animal food
LIVESTOCK
SYSTEM

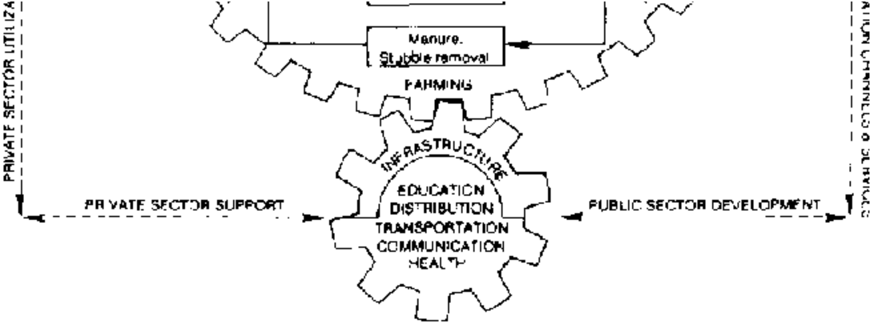


FIGURE 3-1 Pastoral Economies.

We generally think of an agricultural project as an investment activity in which financial resources are expended to create capital assets that produce benefits over an extended period of time. In some projects, however, costs are incurred for production expenses or maintenance from which benefits can normally be expected quickly, usually within about a year.

Range or marginal land development projects (such as seeding) can be viewed in the same terms as an agricultural project, although the investments, costs, and returns may be substantially different in substance and in timing of flows. For example, the returns on a rehabilitation project may take several years to realize depending on the starting conditions and project management. These returns, however, may be in the form of higher stocking rates, which may have caused the problem in the first place.

An alternative approach is to examine potential losses that are avoided through rehabilitation. This approach is similar to determining the benefits of flood control projects. If degradation is not halted, then adjacent agricultural land may be placed at risk.

Gittinger also distinguishes between a project that may be relatively small, or perhaps quite large, but is of a nature that it can be analyzed, evaluated, developed, and administered as a unit. A "program" would typically be larger than a single project, and encompass multiple projects or aspects of development that are beyond the project definition and boundaries.

A project should contain relatively homogeneous resources so that investment requirements, costs, and returns from different parts within the project can be accurately represented. If a project becomes large enough to become heterogeneous, then a part of the project - which may in fact be uneconomical or unfeasible - may be hidden or masked and carried by other parts of the project that are worthy of development. When dealing with scarce resources, the concept of homogeneity within a project is important. Past experience has shown that in many instances projects have failed because of lack of social homogeneity; that is, within the target group of pastoralists, subgroups with contrary interests existed (see, for example, Sanford, 1983).

Economic and Financial Analyses

By definition, the economic analysis compares all returns and costs associated with a project during its useful life. Costs include initial and recurring annual expenditures, whereas the revenues include returns as a result of the project over and above what they would have been without it.

Financial or cash flow analysis is the determination of the project's cash flow positions over the period of the project. This shows whether the project is self-supporting or whether deficits are likely to develop. It is simply to compare revenues and expenditures, including debt service on an annual cash basis. The objective of financial analysis is to consider and make estimates of the effects the flow of project costs and returns will have on people participating directly in the project, including families or community groups that make direct use of the project and the primary users. Financial analyses also must consider administration, management, and taxes of the project and costs to the government and donors for those activities.

In financial analyses, market prices, if available, are used to reflect the value of production. Project returns may also include a very significant contribution in the form of food or fuel consumed directly in the household. If subsidies are paid by the government in association with the development of a project, then that also becomes part of the income to the direct beneficiaries from the standpoint of financial analysis. Financial analysis also considers revenue to the goveronment (taxes) for project administration, which have been considered in the costs of the primary beneficiaries (users).

The "economic" aspects of project analyses and evaluation, in contrast to financial aspects, considers the project from the standpoint of the affected society and economy as a whole. Financial and economic analyses differ in three significant ways:

1. Taxes that are treated as costs to primary project participants in financial analyses are viewed by government and society as revenues, not costs.
2. In economic analysis, market prices may be adjusted and become "shadow" or "accounting" prices or “social costs/benefits" to reflect

more accurately the economic values to society.

3. In economic analysis, interest on capital and repayment of borrowed capital are not treated as project costs. Although interest is a cost to the project, it is a return to society and the economy as a whole, if actually earned, and hence becomes a "wash" item in economic analysis and accounting for the project. Similarly, the repayment of borrowed capital, although a requirement for the project, neither increases nor decreases net national product.

Comparison Without and With a Project

The purpose of project analysis is to identify and estimate benefits and costs that will arise "without" the project and compare them with benefits and costs "with" the proposed project. The difference between them is the incremental or marginal net benefit arising from the project.

The results of the without-with comparisons may be the same as comparing a particular project situation "before" and "after." Often, however, the comparisons are not the same and may be greatly different because productivity may improve (increase) even without a project. Hence, the projection of the without situation would reflect higher productivity and returns than the current or before project situation. The benefits from a project designed to improve productivity at a more rapid rate than would occur without the project would be overstated by a before and after comparison, because improvements without the project are ignored.

Conversely, a different, perhaps more common, and certainly more serious situation could be one of rapid deterioration in productivity and resource or environmental conditions without a project. A project could be designed with the aim of ameliorating or reversing the deterioration; improved productivity could be a distinct bonus. It may therefore be difficult to compare or economically justify such a project when it may only retard the rate of degradation and keep the returns constant. Intangible benefits must then be considered such as the quality of the environment and the costs associated with people moving to urban centers to escape declining land productivity.

Decision Making

A decision needs to be taken that leads to implementation, modification, or cancellation of the project. Certain costs and benefits (payoffs) are associated with any of these decisions. The decision may be to endorse the project and proceed with implementation based on a degree of uncertainty.

Problems and sources of uncertainty are classified in five categories:

1. Price structures and changes (values)
2. Production methods and responses, including weather effects and other natural phenomena (technical input/output coefficients)
3. Prospective technological developments
4. The behavior and capacities of people associated with the project
5. The economic, political, and social contexts in which a range improvement project exists.

All these sources of uncertainty affect the analysis of projects and are factors to be reckoned with in implementation and evaluation of results.

The basic principle for carrying out an economic analysis is to compare alternatives on an equivalent basis, such as a fixed output, time frame, and constant dollar values. In the analysis, the quantifiable assumptions must first be established as follows:

· All baseline project assumptions, such as the period of analysis, discount rate, cost of capital, and other economic and financial variables must be determined.
· Estimates must be made of project costs including capital costs, onetime costs such as permits, annual operating and maintenance costs, and provisions for renewals and replacements. Estimates of fees, construction, labor and materials, and legal fees must all be determined and placed within the desired schedule.
· Project benefits, principally the increased production, must be ascertained.

· The source of financing and the specific terms of the loan must be defined.
· An appropriate economic analysis methodology must be chosen, and economic and financial feasibility must be established.
· A sensitivity analysis must be performed to determine how costs and benefits react to variations in such factors as discount rate, financing, and productivity.
· The persons or groups of persons who gain and who lose by the introduction of the project must be identified; there are always some losers.

The common approach to economic analyses has been to compare costs and revenues over a consistent time period on a ratio basis or net positive benefit basis. Several measures using discounted cash flow techniques can be employed: internal rate of return, benefit-cost ratio, net present value, and life-cycle costs. Each technique has its advantages, disadvantages, and appropriate applications.

Discount Rate

The discount rate is used for determining economic feasibility, whereas the interest rate is used to ascertain financial feasibility. The proper rate to use for testing economic feasibility is the opportunity cost of capital to society. This is the rate of return that could be earned by investing the capital cost of the project in a venture of similar risk or an alternative marginal project.

Discounted Cash Flow

One of the basic tools for determining economic feasibility is discounted cash flow. All cash expenditures are tabulated for comparison during the chosen period each year. The total cash expenditure for each year is then discounted to the present and cumulatively added to a single sum. This sum is then compared with similar sums of discounted expenditures for alternatives. The alternative with the smallest sum is clearly the least costly. A similar comparison is made with cash revenues or receipts for the same period. The ratio between the sum of the discounted receipts and the sum of the discounted expenditures yields the benefit-cost ratio.

Certain rules must be followed in making discounted cash flow analyses:

· The same period of years must be used for each alternative set of cash expenditures and each alternative set of cash receipts.
· The alternatives must have the same production and capacity. In some cases, this may require adjustments to the costs of the lowest cost alternative.
· Cash expenditures will include renewals and replacements; however, if the years in which these will be made cannot be accurately predicted, an estimated average annual cash expenditure for renewals and replacements as well as an accelerated depreciation schedule can be used, since those costs will occur far in the future.

Discounting transforms all future costs and revenues into the present time frame so they can be compared on a current monetary basis. These sums are simply called the present worth or present value. All future expenditures and revenues are modified or discounted by a factor that provides escalation arising from opportunity costs and resource depletion.

The benefit-cost ratio technique is perhaps the most commonly applied in analyzing capital projects. The method compares the current worth of costs and benefits on a ratio basis. Projects with a ratio of less than one are generally discarded.

Determining costs and benefits

Computing costs and benefits involves use of simple without with comparisons. Specific allowances are not made for time lags, except for charging interest for use of capital. Budgeting in such a static framework, or without-with project-context comparisons, can give a first indication of feasibility or nonfeasibility of a rangeresource-improvement project. Simple comparisons ignore time lags in phasing different stages into production and can overlook or ignore costs of capital through the developmental stages, exaggerate returns and feasibility, and underestimate problems that can arise. Budgeting year-to-year estimated changes through the transition period, though complicated, will aid in anticipating some of those problems. If the project resources are suitable and the project is successful, changes in physical production responses on a year-to-year basis may be predictable with some degree of certainty. Price changes often are unpredictable. Evaluations can be based on longer term average prices with year-to-year changes in production. Discounting procedures can be used to allow for valid comparisons of alternatives through time.

Benefits that might accrue from and be attributed to range-improvement projects may include increases in both the quality and quantity of outputs, depending on factors previously mentioned. When considering a resource improvement project that produces an intermediate product, such as forage, then improvement in quality of output may still be important but is of a somewhat different form. These are called intrinsic benefits. For example, improvement in forage quality has one or a combination of the following characteristics:

· Higher protein content
· Lower fiber content
· Higher total digestible nutrient (TDN) content
· Greater palatability to some species of animals consuming the forage.

While some of these characteristics are being improved during the periods of active plant growth, and on through the periods of maturity, an added bonus of residual plant biomass during periods of plant dormancy is also useful for soil conservation. A second benefit could be simply an increased quantity of output.

Marketable output is the benefit most commonly expected from range projects. The increased physical production may result from: (1) improving the productivity of the native resource; (2) expanding the land area in production by conversion of native range, woodland, or jungle land to cropland or improved forage; (3) extending complete or supplemental irrigation water to arid or semiarid lands; or, (4) improving seasonal water supplies, even in more humid areas. Production may also be increased without increasing land area when projects use genetically superior seed, hybridization, fertilizers, or pesticides for control of weeds, insects, or disease. Increased production may result in marketing of the larger amount of products for the benefit of society or may allow greater consumption for the family or the social unit directly involved in the project.

When a resource development project involves forage production and livestock, then increases in forage production can be followed by increases in the number of livestock on the land and a greater yield of consumable or marketable livestock and products. This would produce one kind of effect on flow of returns, as the requirement for increased animals requires a savings (or investment) in addition to the resource development costs. It is also important to recognize that benefits in livestock production may be reflected in increased production of calves, lambs, kids, or young camels without larger numbers of the basic breeding herd.

Overstocking of rangeland is detrimental to livestock production. Increased production of livestock, therefore, can only be considered in light of long-term efforts to improve the range resource. Increased forage supply used only to ameliorate overutilization of rangelands can result in improvement in percent age of calf or lamb crops , in increased gains of growing animals, and probably in reduced mortality of both breeding stock and growing animals. Special use pastures or pastures to fill particular seasonal needs may produce these effects also. Benefits of these types may well be associated with very high returns on resource development costs. Output may also be increased by a simple increase in forage production and expansion of livestock output. Increased forage also makes it possible to increase the number of breeding herd animals; even if they are producing at the same level as without the project, output will increase.

Resource evaluation

Evaluating the quality and adequacy of various resources for possible alternative uses is the first step in project planning. The climate and characteristics of land and soils, water supply (whether for irrigation, livestock, or domestic use), and incidence of weedy types of vegetation, insect pests, and plant or animal diseases should all be considered. The objectives of the evaluation process are to determine the forage and livestock enterprises that may be feasible and whether some alternatives can be ruled infeasible without further evaluation. These factors are described in more detail in chapters 4 and 5.

Location of the project and access to markets both for sale of products and for purchase of necessary supplies is another key consideration for determining feasibility. The location, climate, land, and water supply factors are often fixed. It is impossible, or at least difficult and often costly, to modify these factors. Water supply can sometimes be augmented by drilling wells or creating storage;

however, the ecological consequences must be considered.

Human resources are the most difficult to assess. Most projects rely on organizations of pastoralists. Important questions to address are the following: Will the existing organizations be used, or will a new organization be established? What should be the size of the organization? How complex will be the functional specialization and what type of membership (inclusive versus exclusive, voluntary versus forced) is expected?

A new organization can only be established at a cost. Because of low population densities associated with arid rangeland, communication between members is difficult. Difficulties in decision making, therefore, increase as group size increases. For the same reason (lack of opportunity to communicate), there are limits to functional specialization.

Sanford (1983) emphasizes that the "costs" of project organization are often underestimated if not overlooked altogether. A first step to the evaluation of human resources is a good understanding of the existing social organization.

Data Needs and Sources

Data required for cost and benefit evaluation, frequently called "input-output" data, include: herbage or animal production or possible alternatives; physical quantities of inputs used, whether a product is produced or purchased; prices for inputs; and prices for output to be sold.

The principal sources of physical input-output data for projects may include well-trained professionals with technical expertise in the area, data from other projects of a similar type and under similar conditions, people from the locality with good knowledge of the area and what might be expected, and data from controlled experiments.

Preliminary experiments are very important sources of data for technical specialists who must make judgments about the productivity of resources in new projects. The preliminary experiments do not yield perfect or reproducible results, particularly when applied to international projects of an agricultural nature where factors such as weather, variability in inputs, and the performance of the field crew typically are incompletely controlled. Situations in developing countries lead to what might be called “the experimental gap" between the yields that are obtained on the experimental plots and those likely to be achieved on projects. The technical specialists must attempt to estimate the extent of experimental gap and the extent of adjustment or correction. Farming systems research is attempting to narrow this gap.

In general, local data are most useful for ascertaining the response to different treatments or the change in output resulting from a change in level of the inputs.

Farmers or pastoralists may be the best source of information on crop or vegetation and animal performance, requirements for labor, materials, machinery use, feed requirements, and so on.

Information collected locally by survey procedures can be used to establish benchmarks for current enterprise combinations and production practices, and to obtain crop and livestock labor requirements and machine use levels for operations of different sizes.

Market price determination

A number of problems confound the establishment of prices for use in project planning. Obtaining satisfactory price information is usually not a difficult problem in the United States. Merchants, dealers, and farm operators can usually provide satisfactory information on current levels of prices paid and received and wage rates. In developing countries, however, specific price information may be more difficult to obtain, and short-term price fluctuations are likely.

To the extent that markets exist and market price information is available, market prices should be used, but a few caveats must be considered. First, if market prices are generated from a location remote from the project area, then it would be necessary to make adjustments to account for differences from the project area because of transportation costs, any losses due to waste, spoilage, shrinkage, or death loss, and for transaction costs at the marketplace.

If prices tend to fluctuate in a completely irregular or random fashion or in a cyclical fashion, an average price or expected value may have to be used through a series of years.

Prices are one of the crucial assumptions in planning, and the importance of good price forecasting cannot be overemphasized. However, it is possible to become too fearful and exaggerate the consequences of errors. The effects of different prices can be ascertained quite easily by "sensitivity analysis" after the major budgets have been prepared. This may be desirable, both to test the stability of a particular budgeted solution against variations in prices, and also to ascertain the amount of possible loss if the price assumptions are in error. The probability of different occurrences may also be assessed.

In project planning, the determination of prices is a problem if satisfactory market or price reporting systems do not exist. Often the only valid way to place a value on forage is indirectly, by determining its value through the livestock production process. In that case, the costs of producing the forage as an intermediate product could be used. Placing a price on the forage directly is unnecessary.

As mentioned earlier in the chapter, valuation problems are very difficult for the so-called non market or social considerations involved in improvement and rehabilitation practices. For instance, it is very difficult to place values on such things as enhanced erosion or flood control, dune stabilization, or enhanced wildlife production. However, damage mitigation analysis (as used in water resource projects) can be applied. In such a situation, the before analysis would overstate the without analysis and the before-after comparisons would understate the benefits of the proposed project compared with the without-with comparison.

The analyses based on the without-with approach to projections is generally more complicated because it does require projections of two situations. The current before situation can only be taken as a data base or benchmark and guideline information. A before-after type comparison is based on the current situation as one projection and only one projection is required for the relatively unknown after situation.

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Regional resource assessment

The purpose of a regional assesement is to develop a general overview of the project region that will be used in planning. Assessment includes describing the physical and biological character of the land and its historical and current uses. With this information, one can estimate economic opportunities or the capability of the lands within the region, and identify potential problems that might be encountered under different management regimes or land use practices.

This chapter deals with the more detailed, site-specific evaluation that is necessary before any range improvement project can be implemented. The first part of the chapter examines the types of information required for a resource assessment and how they are used. The second part describes techniques for acquiring this information, with special emphasis on remote sensing.

Information needs

The objectives of the resource assessment, which are to provide information for general planning, are:

· To determine the general nature and condition of the resource base in the project region;
· To identify the areas within the region that are of special concern;
· To establish the relative importance of each area according to the objectives of the project; and
· To develop a realistic plan of action based on the assessment.

Maps and supplementary reports are the products of the resource assessment. The maps show the location and extent of different types of land in relation to other lands. Because a general overview is required, map scales are commonly smaller than 1:100,000.

In the mapping phase of a resource assessment, the region is surveyed and divided into areas that are relatively homogeneous in some property such as vegetation, soil, or land use. At the scales considered here, however, only broad patterns can be mapped.

Mapping units will be somewhat heterogeneous and will contain a number of different site types. An important purpose of the report is to relate this diversity by describing the nature and composition of the mapping units.

Mapping units are not necessarily predefined and may be designed to meet the needs of a project. These mapping units will become the physical units around which the study project is organized and probably will become the units used for many future land management decisions. Thus, criteria used to define basic mapping units must be carefully selected. In a resource assessment for range improvement, units should contain areas that (1) have about the same capacity to sustain one or a set of land uses, and (2) require similar kinds of management. This characteristic of land is generally called "land capability" and is determined by a number of factors, such as climate, vegetation, wildlife, and soil.

Climate

Climate is perhaps the most important factor in determining land capability because of its direct impact on the immediate resource, such as forage, and its role in determining the types of vegetation and soil found in a region.

The climatic data required for a resource assessment are those that influence the development of soil and the distribution of vegetation. Average annual temperature, seasonal extremes, frost-free period, evaporation, and precipitation amounts and their seasonal distribution are the most important considerations because they help determine soil type, water availability, vegetation type, and potential plant productivity.

Although climate is important in determining land capability, only broad generalizations are expected at the resource assessment level. The purpose is to identify relatively homogeneous climatic zones that could support one or a limited set of vegetation types.

Vegetation

Since climate cannot be observed directly, vegetation patterns often are mapped and interpreted as indicators of climate. Many assessments produce a composite map of climate and vegetation. Intended to serve as an indicator of climate, it is also an important management tool. An examination of the environmental history of the region and previous resource assessments, as well as an interpretation of the information generated during the mapping phases of the resource assessment, allows the development of a profile of the type of vegetation that might be found in different parts of the region under "natural" conditions. This model of potential or climax vegetation ultimately may serve as a guide for range improvement by suggesting what might be achieved.

It is also necessary to inventory actual vegetation patterns currently found within the region. A vegetation inventory includes maps and descriptions of associations, at a minimum, and could also include information on cover, production, and numbers of plants. Special attention should be given to determining the value of component species for forage, fuel, and other uses.

At this level of study, the goal is to provide information on the distribution of resources and, by comparing the results with the estimate of potential or climax vegetation, to identify areas where there are opportunities for range improvement, and to indicate areas where problems exist. Perhaps most important, the inventory of actual vegetation provides a picture of conditions at the beginning of the project that can serve as a benchmark for measuring general progress during the course of the project.

Geology

At the resource assessment level, geology is described in general terms. Primary consideration is given to identifying rock type and structure within the region. Geologic information provides a structural framework for the region and also is used to help form a general understanding of regional hydrology and the evolution of landforms and soils by providing clues to the origin, age, and mineralogical composition of surface materials.

Landform

Landform is the feature commonly used to unify or provide a framework for the mapping aspects of the resource assessment. In most cases, landform is the most readily mapped feature of the landscape, and it is frequently correlated with other, less easily observed features, such as hydrology or soil. Not surprisingly, some vegetation types within the region may be consistently associated with a particular soil. Thus, an understanding of regional landform-soil-vegetation relationships is a powerful and necessary tool in developing the physical base of a resource assessment. An analysis of information on landform provides a general framework for survey while indicating some of the areas that might be especially susceptible to erosion. These areas would warrant special attention in a range improvement project.

Soils

Along with climate, soil type ultimately determines land capability.

At the resource assessment level, however, only general soil information is gathered. This includes soil texture, soil morphology (that is, depth and presence of limiting horizons), general soil chemistry, and susceptibility to flooding or erosion. Ideally, many soil properties can be inferred from climate, landform, slope, and existing land use.

Soil types are not mapped at the resource assessment level unless the environment of the region is very simple. More typically, natural groupings of soil types, such as soil associations, are mapped. Although soil types are not mapped, descriptions of them are acquired to portray the range of conditions that will be found within the broader mapping unit.

Water

Delineation of watershed boundaries, major drainage lines, and other hydrologic features (for example, dry lakes) can help develop a general hydrologic framework of the region; it can also help facilitate the interpretation of landforms and soils, and can provide a general view of the likely distribution of water resources.

In most arid and semiarid regions, the distribution and quality of surface and near-surface water in an area will restrict the number of options for range improvement and subsequent management, and will have a major influence on the course of the project. Thus, a resource assessment must locate sources of surface water such as springs, streams, lakes, ponds, impoundments, and irrigation works, as well as average seasonal flows or volumes. Proven subsurface resources also must be reported by noting the location, depth, and yield of wells.

Current and Historical Land Use

Descriptions of land use are important for at least three reasons. First, one of the primary purposes of the resource assessment is to provide an overview of the mix of regional land uses. A comprehensive description of land uses will provide a general reference and may suggest functional economic linkages between land uses, such as irrigated agriculture and animal grazing systems. Any range improvement project must consider the relationships that exist between adjacent land uses.

Second, the land uses and management practices found within a region give some indication of variations in land capability. For example, pastures that are used only seasonally may be limited in their productivity because of cold winters or spring flooding. Such lands would require special consideration.

Third, some range improvement problems are associated with specific land uses, such as urban developments and woodcutting in many places, and should be identified for special treatment.

Like climate, some land uses are difficult to observe. Because of the ambiguous distinctions between some types of vegetation and land use (rangeland, for example), they are sometimes mapped together. A common compromise is to map "land cover," which includes all observable features that cover the land surface, such as vegetation, surface water, and various land uses (urban development or agriculture, for example).

Information on current land use should include maps and descriptions of all land uses, settlements, infrastructure (roads, canals, rail lines, fences, wells, and other watering points), and population estimates. Descriptions of regional land tenure practices may also be useful in explaining some land use patterns and management problems.

The patterns observed now may not be directly attributed to current land use practices. Historical events or land uses that are no longer observable may have left profound impacts on the land.

For example, highly saline rangelands may have been irrigated at one time and later abandoned because of salt accumulation. Thus, a general description of previous land uses, land use practices, and their locations may be useful in understanding current problems.

Moreover, the successes and failures of the past may provide good evidence of what might be expected and how changes in management alternatives might be developed during the project.

Livestock and Wildlife

At the resource assessment level, it is necessary to produce a general census of animal herds within the region. Information gathered might include herd location, size, composition, general condition, and seasonal movement. In addition, the forage preferences and consumption patterns of the largest groups and their place in the local economy should be noted. With this information, range resources can be described in terms of forage demand, and the general economic and social impacts of alternative animal management plans can be projected.

Information acquisition

Decisions concerning how the survey and other information gathering activities will be performed should be made at the outset of the resource assessment. Although this will not affect the type of information that is collected, it will determine, in part, how it is collected and organized.

Survey Approaches

Resource assessment might be approached in two ways: the component approach, in which each land characteristic is mapped individually, and the landscape or land systems approach, in which land is viewed as an integrated whole and the units that are mapped are more or less homogeneous. In both approaches, land characteristics are analyzed together to derive an estimate of land capability.

Component Approach

In much of the world, including the United States, agencies have been established to study individual resources (for example, climate and soils) within the country, or have been assigned to manage specific types of land use (for example, forest and rangeland). Both types of agencies conduct their own mapping activities. Thus, in a range improvement project, it is common to find that one or more land characteristics (for example, geology) have been mapped already for much of the project area. With this pattern established, a project will likely continue mapping land characteristics individually in the interests of consistency and economy. Moreover, project mapping may be carried out by several groups on a component basis because of the distribution or resource responsibilities among participating agencies.

Because it is difficult to map certain land characteristics individually, some characteristics often will be combined in one map (for example, climate and vegetation; vegetation and land use/land cover). Because of the constraints of scale, mapping units will tend to be somewhat heterogeneous, but will be designed around naturally linked groupings of land characteristics (for example, associations of soil or vegetation).

Landscape Approach

The need to adopt a systems approach during most phases of a range improvement project is emphasized throughout this volume. Two considerations argue for the systems approach at the resource assessment level. First, as noted above, the region should be understood in terms of its differences in land capability. This quality of the land is derived from physical and biological characteristics such as climate, soils, and vegetation. Although these characteristics may be surveyed individually, they must be considered together to determine land capability. Moreover, the units of land that are mapped function more or less like systems and not simply as a collection of independent components. Change in any one of the components will affect or be affected by other components in varying degrees. Thus, at the resource assessment level, it is desirable to consider the units of land to be managed as integrated "landscapes" with a distinct set of related characteristics.

Second, from a practical standpoint, significant economies of effort and improvements in product quality can be achieved by combining related or complementary aspects of the resource assessment. For instance, in a landscape approach, an interdisciplinary team (perhaps a soil scientist, geomorphologist, and plant ecologist) performs the mapping and analysis tasks as a group, rather than producing a set of individual maps and reports. Field expenses are reduced by combining activities, and mapping consistency and analysis quality are improved by complementary collaboration.

The landscape or land systems approach to resource assessment was developed and applied first in Australia after World War II. The problems faced there were not unusual: large areas of the country had to be surveyed quickly and accurately to determine their agricultural potential. This highly successful approach is still used in Australia. Comparable approaches have been developed by other countries in many parts of the world for agricultural, military, and engineering purposes. In the following discussions, the Australian terminology is employed.

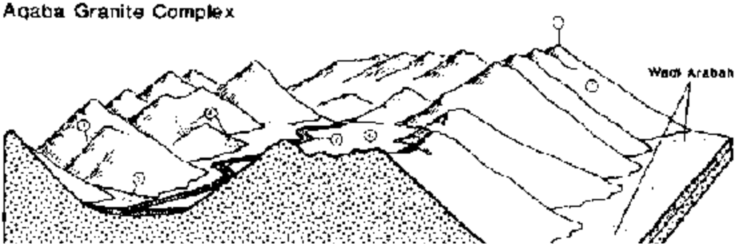
The land systems approach has a hierarchical structure of units (figure 4-1). The smallest unit of land recognized is the land element. It is defined primarily by slope, and is essentially homogeneous in all properties, corresponding to the concept of "site." Because of its limited extent, it is never mapped at the resource assessment level, but rather is the primary focus of site evaluation, as described in the following chapter. The next largest unit of land is the land facet, which consists of a set of related land elements, commonly on the same landform. It is seldom mapped in a resource assessment. The land system is the largest unit, and consists of geomorphologically and geographically associated patterns of land facets. The land system is the most commonly used mapping unit in this approach and is well suited to the general purposes of the resource assessment.

Information Acquisition Methods

Archival Research

A search of archival sources of information is done at the beginning of the project to gather the work that has been done to map and describe land characteristics of the region. This avoids a duplication of previous work, and builds on the experience and insights of other workers in the region.

Published information on land characteristics exists for essentially all parts of the world. The types of information that can be found include maps and descriptions of climate, soil, and vegetation. Most of this information is extremely small in scale (for instance, world or regional maps produced by the United Nations Food and Agriculture Organization). Although continental-scale maps are not suitable for a final assessment, they are a useful starting point.



AQABA GRANITE COMPLEX

Climate: Desert

Physiography: Dissected granite hills

Geology: Includes acid and basic igneous rock. Porphyry and narrow dolerite dikes locally prominent

Land facets:

No	Form	Soils	Vegetation
1	Crest, bare rock	Lithosols	V. thin scrub
2	Bare rock slopes, including porphyry and dolerite dikes		(8a)
3	Wadis	Bouldery, stony and sandy regosols	Rather sparse scrub. *Acacia* spp., *Retama raetam* (4bb, 4s, or 10b)
4	Steep screes and coarse block fans	Boulders	Sparse, deep-rooted chenopods and shrubs

			(6c. 4h)
5	Gravel fans (smaller stones than 4)	Gravel	Sparse *Haloxylon salicornicum* (4h)
6	Desert flats, including small wadis	Stony and sandy regosols	ND*
7	Mud flats	Salt and clay, saline	Almost bare

* ND= No data

FIGURE 4-1 An example of land systems mapped in Jordan. (Mitchell and Howard, 1979)

Moreover, general reports usually contain extensive bibliographies that may lead to more specific studies for the project region.

Many papers are published in professional journals as a product of scientific studies conducted in a region. Commonly, these papers will describe one particular aspect of the region, such as overgrazing and erosion, that will not be critical to the total resource assessment, but may provide some insight into a particular problem in one part of the region. Descriptions of these papers can be found in science indexes and abstract journals, either by topic or by geographical location.

As noted above, maps and reports describing various land characteristics in a region are produced by regional, national, and international agencies. Because these materials may not be widely distributed, and their existence may not be generally known, inquiries must be made at all levels to find what work may have been done within any one region. Finally, some types of information, such as land ownership or census data, may be available only from local or regional archives.

All of the information needed for a resource assessment probably will not exist in a usable form at the start of a project. For example, vegetation maps are relatively uncommon, and any existing maps for a region may have been done for a purpose that is not compatible with the objectives of the project (for example, a map of forest resources will be quite detailed for forested areas but may describe non forested lands only as "rangeland"). In other instances, existing maps or data may be out of date. Thus, in most resource assessments a good deal of map and supporting information must be gathered and compiled independently during the project. Some of the more commonly used techniques for generating this information are discussed below.

Interviews

Discussions with local administrators, researchers, and especially land managers can be conducted to gather information on those characteristics that cannot be directly observed and that are probably not recorded, such as land use, land management practices, animal management practices, general management issues, economic conditions, land capability, local perceptions of resources, and any other information that may support specific project objectives.

As suggested above, background information can be extremely

important in estimating land capability in terms of indigenous practices. It also should provide some clues about the acceptability of proposed changes in management practices.

Interviews may be conducted formally, and may rely on the use of questionnaires if the objectives of the project call for a quantitative description of some features of local culture. However, informal interviews are done more easily and may serve equally well.

Ground Sampling

Much of the information required for the resource assessment can be gathered only through direct observation. This information may be used to develop maps, to develop estimates of the magnitude of other characteristics that are not ordinarily mapped (for example, population), or to describe the composition of mapping units (for example, vegetation species and cover, and soil type and depth) that have been recognized by other means (see the following section on remote sensing).

Maps and estimates of land characteristics may be developed in two ways. First, ground samples may be gathered in a sampling pattern such as a grid. Reasonable maps or estimates may be developed from such data. However, the accuracy of this approach is dependent upon the complexity of the region and the density of sample points. At the resource assessment level, it is unlikely that a project could afford the expense of allocating enough samples to characterize a large region. Thus, systematic ground sampling is used only for very intensive studies, such as irrigation soil surveys, or where the features of interest are assumed to be poorly correlated with other observable features, such as archaeological sites.

A second approach employs stratified sampling and is used where it is possible to assume a reasonable correlation between two or more characteristics. For example, in a landscape approach to survey, it is possible to stratify an area according to landform and elevation if good topographic maps of a region exist. Ground samples are allocated to each stratum, according to its importance or complexity. Maps and estimates developed in this way are reasonably accurate and more efficient than a systematic approach.

However, dynamic land characteristics, such as land use and vegetation, may be inadequately sampled because of their high variability. For example, major changes in vegetation resulting from clearing or fire may be missed because they are not necessarily correlated with landform.

Remote Sensing

Although maps and estimates of land characteristics can be produced by ground sampling alone, it is seldom done for a resource assessment because of the expense and the likelihood of missing important features.

Remote sensing is the most commonly used tool for gathering information for large areas As defined here, remote sensing includes the uses of aerial photography and satellite imagery to study the earth's surface. Remote sensing data are unique because they (1) provide a comprehensive picture and permanent record of surface conditions at one point in time and (2) present a vertical perspective in which all features are represented, essentially in their true geometric relationship with all other features. There is no ideal remote sensing system. Thus, a primary task in remote sensing is to select a system that best meets the needs of the project.

Principles of Remote Sensing Remote sensing exploits the differences that can be detected among surface features on an image of the earth. The ability to distinguish among features is conditioned by several factors. Foremost in many applications is the feature's tone or color. Earth materials reflect or emit electromagnetic radiation, including light, in different ways (figure 4-2). For example, vegetation has a unique pattern of reflectance, with moderate reflectance in the green part of the spectrum, low reflectance in the red part of the spectrum, and very high reflectance in the infrared part of the spectrum that is just beyond what is visible to the human eye. Second are those inherent properties of a feature that determine how it appears, or what is sometimes called a feature's "signature" or "response." The characteristic shape of a surface feature when viewed from above (for example, a folded geologic structure) or its relative size (such as tree versus shrub) are two such properties. Other important characteristics are less obvious, such as a feature's “texture" on an image (say the difference between the smooth texture of a meadow and the rough texture of a forest canopy), or the association of one feature with others (such as pine forests on steep north-facing mountain slopes).

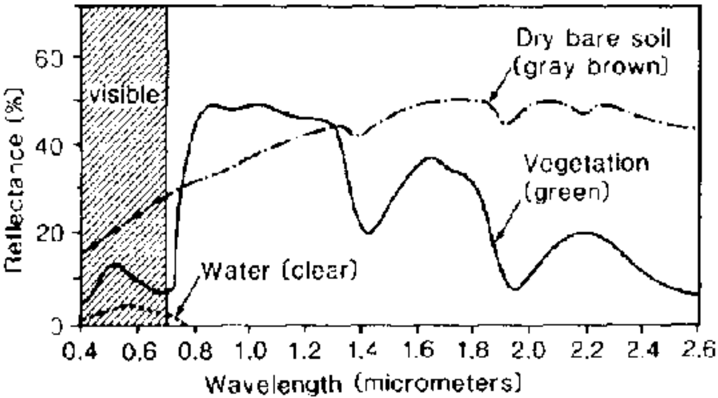


FIGURE 4-2 Spectral characteristics of different earth materials.

The type of remote sensing system used also affects the ability to distinguish among earth features Scale - the relationship between the size of the image and the area on the ground it portrays - largely determines what can be seen, especially if geometric properties such as size, shape, and even texture are noted. Other important characteristics of remote sensing systems have to do with system resolution, or its "sharpness" in several dimensions - spatial, temporal, and spectral.

Spatial resolution broadly describes the quality of the system that determines the smallest feature that might be detected. Thus, spatial resolution influences the ability to detect features based upon geometric characteristics. For example, to determine tree densities in savannah vegetation, relatively high-resolution images would be required to see individual trees, while simply to map the boundary between forest and savanna, low-resolution images might be preferred to enhance differences in total tree cover rather than the location of individual trees.

Temporal resolution describes how often a system acquires images for a single point. Although not usually a consideration for aerial photography, temporal resolution is an important characteristic of satellite systems because they operate continuously. For example, mapping forests in a large area and also distinguishing between evergreen and deciduous types would require a system that acquires images frequently enough to assure at least one cloud-free image from both summer and winter.

Spectral resolution describes the location and width of the parts (bands) of the spectrum in which the system records. Earth materials reflect and emit electromagnetic radiation in different ways. To improve the ability to discriminate features it can be useful to employ a "multispectral" approach by examining several different parts of the spectrum. The value of this approach is easily appreciated when comparing a black-and-white panchromatic photograph with a color photograph. Color photography provides much more information than black-and-white, but it tends to have poorer spatial resolution, is more expensive, and is difficult to process in some parts of the world because of the lack of proper equipment.

There is much information outside the visible spectrum that would be useful for studying vegetation (table 4-1). Photographic films have been developed that are sensitive to infrared radiation that is just beyond the visible part of the spectrum. Color infrared (CIR) film is the most common type. To record infrared energy using conventional photographic technology, colors from the natural environment are assigned to other colors on the CIR film. Thus, the final product is sometimes called a false color image: blue is filtered out, green is recorded as blue, red is recorded as green, and infrared is recorded as red. Because plants reflect more infrared light than green light, green vegetation appears as various shades of red or pink. Red soils are yellowish-green, and urban areas are bluish-gray. CIR photography is especially effective for mapping vegetation, but is expensive and sometimes difficult to expose and process.

Nonphotographic sensing systems can be carried by aircraft and spacecraft and provide similar kinds of spectral information. Nonphotographic systems have a number of advantages. For example, parts of the spectrum that are critical in some applications and that are beyond the capability of photographic systems, such as the thermal and microwave (radar), can be sampled. Also, many nonphotographic systems record images digitally, which allows several processing options (see below). With the exception of Landsat satellite data, however, nonphotographic imaging systems will be used in few resource assessments because of the expense of processing and the need for special computer facilities.

Satellite Systems Since 1972, satellite imagery suitable for land resource assessments has been produced continuously for most parts of the world. Landsat was the first satellite to provide regular and universal image data and continues to be the most widely used system.

	Landsat Multispectral Scanner (MSS)	Landsat Thematic Mapper (TM)	NOAA Advanced High Resolution Radiometer (AVHRR)
Cycle	18 days (Landsats 1, 2, and 3)		Daily

	18 days (Landsats 4 and 5)	16 days	
Swath width (kilometers)	185	185	2,600
IFOV/ resolution* (meters)	80	30	1,100
Spectral band nos. and corresponding wavelengths (micrometers)	1) 0.5 - 0.6 2) 0.6 - 0.7 3) 0.7 - 0.8 4) 0.8 - 1.1	1) 0.45 - 0.52 2) 0.52 - 0.60 3) 0.63 - 0.74 4) 0.76 - 0.90 5) 1.55 - 1.75 7) 2.08 - 2.35 6) 10.04 - 12.50	1) 0.58 - 0.68 2) 0.72 - 1.10 3) 3.55 - 3.93 4) 10.30 - 11.30 5) 11.50 - 12.50

* Instantaneous Field-of-View Resolution

Table 4-1 Comparison of Landsat MSS, TM, and NOAA AVHRR

Table 4-1 Comparison of Landsat MSS, TM, and NOAA AVHRR System Characteristics

	Landsat (MSS) Multispectral Scanner	**Landsat Thematic Mapper (TM)**	**NOAA Advanced High Resolution Radiometer (AVHRR)**
Cycle	18 days (Landsats 1, 2, and 3) 16 days (Landsats 4 and 5)	16 days	Daily
Swath width (kilometers)	185	185	2,600
IFOV/ resolution* (meters)	80	30	1,100

Spectral	1) 0.45 - 0.52		
band nos..	1) 0.5 - 0.6	2) 0.52 - 0.60	1) 0.58 - 0.68
and correspond-	2) 0.6 - 0.7	3) 0.63 - 0.74	2) 0.72 - 1.10
ing wavelengths	3) 0.7 - 0.8	4) 0.76 - 0.90	
(micrometers)	4) 0.8- 1.1		
		5) 1.65 - 1.75	
		7) 2.08 - 2.35	
			3) 3.65 - 3.93
		6) 10.04-12.50	4)10.30-11.30
			5)11.50 -12.60

* Instantaneous Field-of-View Resolution

SOURCE: Adapted from the Final Report of the Panel on the National Oceanic and Atmospheric Administration Climate Impact Assignment Program for Africa, BOSTID, National Research Council, Washington, D.C., January 1987.

The primary instrument on Landsat is the Multispectral Scanner (MSS), which records images of the earth in four spectral bands (see table 41). Images are recorded digitally but are produced in both digital and photographic formats. The MSS creates an image by recording the relative brightness of each element or cell of a large array. Each picture element (pixel) equals an area on the ground of approximately 0.5 hectares (60 m x 80 m). An image is created for each band in the green, red, and two infrared parts of the spectrum. Images from each band may be combined to create an image that is similar in color renditions to a conventional CIR photograph, and may be interpreted manually. Because they exist in digital form as well, images may be processed statistically using a computer. Although spatial resolution is relatively low, the MSS is well suited to resource assessment because a single image covers a large area and, as suggested above, it is desirable sometimes to avoid the confusion introduced by detailed data.

The most recent series of the National Oceanic and Atmospheric Administration (NOAA) weather satellites has carried the Advanced Very High Resolution Radiometer (AVHRR) instrument. The AVHRR has low resolution (see table 4-1) because it was intended to complement conventional very-low-resolution weather satellite systems by acquiring data that could be used to describe general land surface conditions. Although AVHRR has been used mainly for monitoring studies, it might provide useful information for exceptionally large regions.

Aerial Photography Aerial photographs are the most widely used form of remote sensing data. They are routinely acquired in most parts of the world for a variety of purposes, including geophysical surveys and the production of topographic maps.

The principal advantages of aerial photography are its high quality (conventional image format is about 23 cm x 23 cm) and the ability to schedule photographic missions at the proper time and appropriate scale using the desired films and filters. Moreover, aerial photography firms can be contracted to fly missions over almost any area in the world. The primary disadvantage of conventional aerial photography is its relatively high cost.

To counter the high costs of conventional aerial photography, increased use has been made of 35 mm cameras for aerial photography (figure 4-3a and 4-3b). Because the film format is so small, most 35 mm photography has been acquired at very large scales from low flying light aircraft. Images from these systems are of somewhat lower quality than conventional aerial photography and they must be used with some care. The advantages in cost and flexibility, however, seem to offset most other considerations when the 35 mm system is used for resource assessment.

Use of Remote Sensing Data

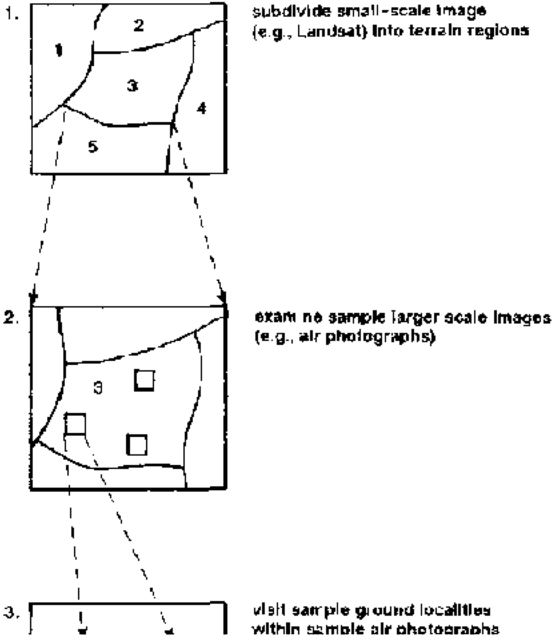
Aerial Photograph Interpretation Satellite images or aerial photographs can be interpreted manually by a trained analyst who is familiar with the study region (figure 4-4). As in any mapping exercise, the objective is to recognize areas that are more or less homogeneous in one or several properties. Using knowledge of the region and the image characteristics, the analyst examines the image and manually delineates areas judged to be homogeneous. areas or mapping units that appear to be related (for example, sandy alluvial fans) are labeled accordingly. These mapping units can serve as strata for subsequent sampling. Boundaries are determined, and mapping unit descriptions are generated by examining large-scale aerial photographs or by analyzing ground samples.

Single images are rarely used in remote sensing. The preferred approach is to examine a number of images at scales larger than that of the base map; larger-scale images are used to refine or label mapping units defined at higher levels Ultimate verification is provided by ground sampling This multiple strata sampling scheme is called the multistage approach to remote sensing (figure 4-5). The multistage approach is used with all types of remote sensing data but is especially effective when satellite images are being used.

Photo Sampling Several other types of information must be gathered during the resource assessment that are not normally mapped by remote sensing (including human population, herd sizes and composition, and detailed land use). Although much of this information might be gathered through ground sampling or interviews, other techniques have been developed for using large-scale (larger than 1:1,000) 35 mm photography as a supplement for ground sampling. For example, a rich methodology has evolved for the use of low-level photography for studying rangeland and large animals in East Africa (International Livestock Centre for Africa, 1981). These systems use the aerial photograph as a sample point in a systematic sampling scheme. Detailed interpretations of the photographs are used to develop accurate estimates of the sizes of domestic and wild animal herds, human populations, crops, and land use at the ranch level for very large regions at comparatively low costs.

Digital Processing Satellite images are available in digital format. These data may be selectively enhanced to produce images that are more easily interpreted by the analyst. For example, if the project is located in a region dominated by bright sandy soils, the contrast at the brighter end of the tonal range can be increased at the expense of the darker. This type of enhancement would bring out subtle differences in brightness that otherwise might be overlooked (figure 46).

Applicability and Availability of Remote Sensing Data Remote sensing may be the only way to acquire information about basic land resources in many parts of the world. Maps of natural resources and land use are relatively rare in many nonindustrialized countries. In fact, adequate base maps that describe topography, roads, and cultural features may not exist for many areas.


1.
subdivide small-scale image
(e.g., Landsat) into terrain regions
1
2
3
4
5
2.
examine sample larger scale images
(e.g., air photographs)
3
3.
visit sample ground localities
within sample air photographs

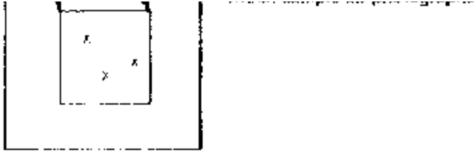
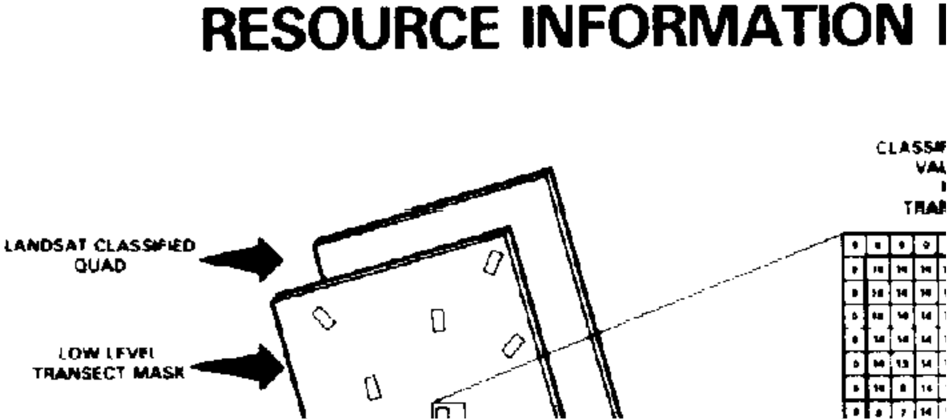
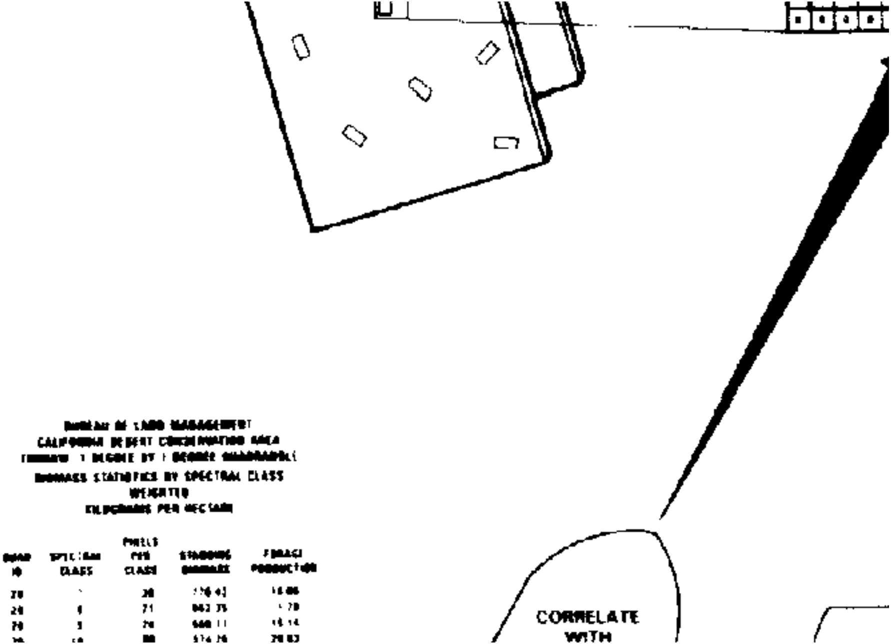


FIGURE 4-5 The multistage approach to sampling as applied in remote sensing (after Townshend, 1981).

Conventional aerial photography is usually the preferred source of information for mapping land resources. As previously noted, however, existing aerial photography may be quite old and thus of relatively little value for mapping current conditions. Even current aerial photography, though, may present difficulties. Because of the great amount of detailed information they contain, conventional aerial photographs are commonly perceived to have considerable intelligence value. As a result, their distribution is sometimes controlled by military authorities and thus may not be available.

If the project is large enough, acquisition of aerial photography may be a major activity and warrant special attention. A large number of private firms provide aerial photography services. Their names and addressses can be found in the telephone books of major cities or in directories of the journals of major professional societies, such as Photogrammetric Engineering and Remote Sensing, the journal of the American Society of Photogrammetry and Remote Sensing.




BUREAU OF LAND MANAGEMENT
CALIFORNIA DESERT CONSERVATION AREA
BIOMASS STATISTICS BY SPECTRAL CLASS
WEIGHTED
KILOGRAMS PER HECTARE
QUAD ID
SPECTRAL CLASS
PIXELS PER CLASS
STANDING BIOMASS
FORAGE PRODUCTION
CORRELATE WITH

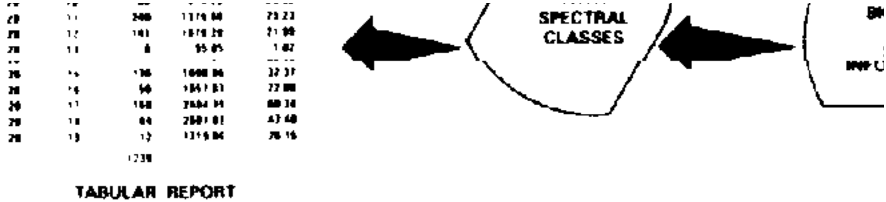


FIGURE 4-6 A method for using digital classification of Landsat imagery for vegetation inventory. Low-level, large-scale aerial photographs were acquired along randomly selected transects. The photographs were used to estimate biomass and soil condition along the sample transects. These values were correlated with the various Landsat spectral classes along each transect. Summary values then were calculated by multiplying the area of each spectral class by the vegetation and soil values derived from the sample transect data for the entire study area. (Courtesy of Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, McLeod and Johnson, 1981)

Landsat Data Distribution Centers	
NORTH AMERICA	ASIA
National Oceanic and Atmospheric Administration Customer Services EROS Data Center Sioux Falls SD 57198 USA	National Remote Sensing Agency Balanagar Hyderabad - 500 037 Andhra Pradesh India Remote Sensing Division National Research Council
Canadian Center for Remote Sensing User Assistance and Marketing Unit 717 Belfast Road Ottawa Ontario KIA 0Y7 Canada	196 Phahonyothin Road Bangkok 10900 Thailand
	Chairman
SOUTH AMERICA Instituto de Pesquisas Espaciais Departamento de Produao de Imagens	Indonesian National Institute of Aeronautics and Space JLN Pemuda Persil

ATUS-Banco de Imagens Terrestres Rodovia Presidenta Dutra Km 210 Cachoeira Paulista-CEP 12.630 Sao Paulo Brazil	No. 1 P. O. Box 3048 Djakarta Indonesia Remote Sensing Technology Center of Japan Uni-Roppongi Bldg. 7-15-17 Roppongi Minato-ku Tokyo 106 Japan
Comision Nacional de Investigaciones Centro de Procesamiento Dorrego 4010 (1425) Buenos Aires Argentina	Academia Sinica Landsat Ground Station Peoples Republic of China
EUROPE	
EAS - ESRIN Earthneat User Services Via Galileo Galilei 000 44 Frascati Italy	AUSTRALIA Australia Landsat Station 14-16 Oatley Court P. O. Box 28 Belconnen A.C.T. 2616 Australia
AFRICA National Institute for Telecommunications Research ATTN:	

Satellite Remote Sensing Centre P.O. Box 3718 Johannesburg 2000 South Africa	

The United States has maintained an "open skies" policy in the acquisition and distribution of data from the Landsat satellites. Since the initiation of the Landsat program, ground-receiving stations have been established in a number of countries around the world (see list below). Images from these stations are available at a modest cost and cover most parts of the earth (see table 4-1).

Where large areas are studied and extensive ground sampling poses a problem, large-scale aerial photography may be required to supplement satellite data and conventional aerial photography. This is particularly true when the efficient multistage sampling approach is employed. Nonconventional systems have been developed (see figures 4 3a and 4-3b) that provide excellent data at low cost for large areas (International Livestock Centre for Africa, 1981). Where budget presents no problem, conventional aerial photography can be purchased from a service.

The variety of remote sensing systems currently available ensures that basic information on land resources can be produced quickly at reasonable cost for almost any country. Should training or re-training be necessary to benefit from these systems, practical training courses are available at most major agricultural universities, and at many remote-sensing centers. Aside from short-term courses (less than one month duration), university training is generally part of a longerterm advanced-degree program. However, a variety of variable-duration, comprehensive training programs in all aspects of remote sensing are available under Unesco auspices through the International Institute for Aerial Survey and Earth Sciences (ITC), 350 Boulevard 1945, P.O. Box 6, AA Enschede, The Netherlands.

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Site evaluation

One of the key elements of a range improvement program is the proper selection of sites for demonstration projects. To ensure success, a site must be carefully chosen and must be typical of the particular ecosystem being considered for an extensive program.

The types of information that are needed at the larger scale, more extensive planning level, and the methods by which this information might be gathered and subsequently used, have been described in the preceding chapter. Analysis of this information should help identify specific areas for potential improvement. In many instances, however, a more detailed site evaluation is required before initiating activities. A preliminary site evaluation can be achieved, in part, through an intensive search of the literature. On-site surveys and observations may still be necessary to complete the site assessment and fully evaluate the site's potential for improvement.

An ecosystem perspective

A site for a proposed range improvement project or program is a microcosm of a larger ecosystem. Regardless of how it is delineated, an ecosystem is the basic unit of ecology, typically a complex system, comprising the physical setting, plants, animals, and its human population. Compounding this complexity is the fact that an ecosystem is almost always changing, even in semiarid and arid rangelands.

The natural process of change in the composition of an ecosystem is referred to as succession. Successional changes take place in response to natural or man-made influences in the environment. So-called primary succession happens on newly exposed areas, such as landslides or sand dunes, whereas secondary succession occurs after the previous vegetation has been destroyed or disturbed by fire or agricultural practices, for example. In many areas of Africa and Asia, a disclimax (a climax maintained through disturbance) has been established through savanna burning and heavy use pressure by livestock. In any case, natural ecosystems evolve from essentially bare areas to more or less stabilized types of dominant vegetation through a series of successional stages.

The current successional stage of a site being considered for improvement should be characterized. Some individual plant species grow better when in competition with existing vegetation on sites in the early stages of succession. Other plant species survive and grow with existing vegetation on sites in later stages of succession. Through recognition of the current successional stage, the species to be planted and managed can be better matched with the successional condition of the site, thereby enhancing the probability of continued growth.

Knowledge of successional patterns is gained, in general, from analyses of systematic, long-term observations of cyclical processes by astute ecologists. These analyses are difficult where successional change is orderly, and they are next to impossible where the changes are erratic. Nevertheless, the potential for the improvement of a site is put in a proper ecological perspective when analyses provide approximations of the current successional condition with respect to the range of successional stages that characterize a site.

A systems approach to site evaluation

A systems approach should be adapted in a site evaluation for assessing potentials for range improvements. Otherwise, the effort might simply be a collection of discrete, often incomplete, and generally unrelated exercises in measurement.

A systems approach to problem solving, regardless of its nature, generally involves a holistic study of the interacting elements that function simultaneously for an explicit purpose, emphasizing the connections among the various parts that constitute this whole. The interacting elements of concern function in "driving" the ecosystem processes. By its very nature, a systems approach to designing a comprehensive site evaluation involves several disciplines, including meteorology, soil sciences, and biology.

It may be impractical (or unnecessary) to measure all of the parts of an ecosystem in a particular site evaluation because, in many instances, only a relatively small number of limiting components may be related to the success of the range improvements. With a systems approach, however, the probability of overlooking important, possibly constraining, attributes will be greatly lessened.

Evaluation of abiotic and biotic components

A site evaluation focuses upon two broad sets of components: nonliving (abiotic) components and living (biotic) components. Climate, soil, landform and relief, and water resource are abiotic components; plants and animals of all forms, including humans, are biotic components. The objectives of the proposed range improvement project or program, the complexity of the ecosystem being evaluated, and the completeness of the available relevant knowledge will largely determine the intensity of the effort to be undertaken in evaluating these abiotic and biotic components. Details of measurement and sampling techniques may be found in Avery (1975), Bell and Atterbury (1983), Brown (1954), Cain and de Oliveira (1959), Carmean (1975), Child et al. (1984), Conant et al. (1983), Jones (1969), Lund et al. (1978), Lund et al. (1981), National Research Council (1962) Schemnitz (1980), and Soil Resources Inventory Group (1981).

Abiotic Components

Reasons for evaluating specific abiotic components of a site are discussed below. Techniques commonly used to quantify these components are briefly described.

Climate

Climate can be defined as the total complex of weather conditions and its average characteristics and range of variation over an appreciable area of the earth's surface. Conditions over an extended period of time are usually taken into consideration. weather in turn, comprises a set of atmospheric conditions at a specified point in time and, therefore, refers to events. Climate is basic to an ecosystem because of its significance in soil development and plant productivity.

Climate is difficult to characterize, owing to frequent deficiencies in the length and consistency of necessary meteorological records.

The climate of a site is most easily described from records of the United Nations World Meteorological Organization or from data collected by national weather offices. Unfortunately, many weather stations from which this information is obtained are often poorly distributed, especially in semiarid and arid lands of developing countries.

Precipitation Patterns The amount and distribution of rainfall is important because of its role as a source of soil moisture. Survival and subsequent growth of plants is, of course, closely tied to the availability of water in the soil mantle. Rainfall, in itself, is usually of little direct significance to plants, although there can be some absorption of water through the leaves and, occasionally, the bark.

Although soil moisture is mostly derived from rain, not all of the precipitation that falls on a site is equally effective in raising the soil moisture content. The slower, more gentle a rainfall event, the greater the penetration, or percolation, of water into the soil. However, a series of precipitation events that totals only several millimeters may add little to the soil moisture content, because the individual events are too widely separated and too gentle to have a cumulative effect. The more severe a drought, especially in dry climates, the greater the quantity of rain required subsequently to alleviate the drought.

Reliable measurements of rainfall are most commonly acquired from networks of rain gauges. There are many types (for example, standard, recording, and totalizer), and dimensions of rain gauges, but they all consist essentially of a funnel with a vertical collar that delivers water to a collecting reservoir. Only precipitation records obtained from gauges located away from eddies caused by physical obstructions should be used in a site evaluation. As a general rule, obstructions overhead should be no closer to the gauge than twice the height (from the ground) of the receiver funnel.

Temperature Regimes Heat from solar radiation controls the temperature regimes near the surface of the earth. The temperature at a site is influenced by incoming solar radiation that, in turn, is modified by secondary heat transfers from terrestrial radiation and air movements. Temperatures of either high or low extremes can be detrimental to the establishment and growth of plants. Hot temperatures, in combination with drying winds, can be damaging to recently emerged plants, especially under conditions of minimal soil moisture. Conversely, cold temperatures can delay seed germination and subsequent early growth, placing the survival of plants in jeopardy. Following establishment, temperatures of either extremes can reduce the overall growth performance of most plant species.

For best growth, many plants require nighttime temperatures that are considerably cooler than daytime temperatures. This difference between nighttime and daytime temperatures, termed thermoperiod, is important in the flowering and setting of fruit. In general, plants will become adjusted to regular diurnal fluctuations in temperatures and, as a result, may not exhibit "normal behavior" when grown in foreign environments. Therefore, individual plant species should be selected on the basis of their adaptation to temperature regimes (including mean, maximum, and minimum temperatures) at a site.

Reliable air temperature data are gathered from simple thermometers (for instantaneous determinations), maximum-minimum thermometers (to measure temperature extremes), and thermographs (for a continuous record of temperatures). Thermometers are generally housed in shelters with louvered sides to permit air to circulate freely. The shelters should be located at a distance at least two-thirds the height of any obstructions. Temperature will vary if obtained on steep slopes or in hollow areas.

The air within plant leaves is usually saturated with moisture under growing conditions, and vapor therefore will move from the leaves into the surrounding atmosphere, cooling the atmosphere in the process; this is transpiration. The rate of transpiration in plants depends in part on the amount of atmospheric moisture present; the drier the atmosphere, the higher the rate of water loss. Transpiration is the dominant process in the water balance of plants and can cause water deficits to occur. Under conditions of limited soil moisture, these water deficits may be responsible for growth reductions or death.

To characterize atmospheric moisture at a site in a given period of time, relative humidity is often measured. With summaries of relative humidity regimes over a growing season, it may be possible to determine the changes of transpiration in plants resulting in water deficits. Because certain plant species are better able to withstand the stresses of water deficits, this knowledge can be useful in evaluating the value of plant species for revegetative purposes at a particular site.

Instantaneous measures of relative humidity are obtained from manual observations of dry- and wet-bulb thermometers on a sling psychrometer. Hydrographs, of which several types exist, are used to record relative humidity on a continuous basis. These instruments should be housed in the shelters containing thermometers.

Wind The effect of wind on evapotranspiration, the total moisture loss from soil by evaporation and plants by transpiration, can be critical, particularly in dry climates. When a plant is exposed to drying winds and hot temperatures, water deficits in its leaves are likely to occur; this situation is compounded under minimum soil moisture conditions. The desiccating impact of wind on plants is demonstrated by low survival rates, stunted growth, and frequently death in many plant communities of semiarid and arid lands.

Data on wind patterns (prevailing direction, velocities, and seasonal fluctuations, for example), characterizing a particular site, are uncommon in many nonindustrialized countries . When this information is available, it has generally been obtained by using an anemometer during short-term site visits.

Light Another climatic factor that affects the growth of plants - an important factor that is seldom measured extensively - is light. Solar radiation in the visible bands of the spectrum controls photosynthesis. At very low light intensities, photosynthesis may take place at such a slow rate that all of the carbon dioxide evolved by respiration is not used; with these conditions, carbon dioxide is given off by the plant, not absorbed by the plant from the atmosphere. On the other hand, high light intensities promote rapid transpiration, which can often have detrimental effects. In general, individual plant species differ in their relative tolerances to either low or high intensities of light.

The photoperiodism of plants also differs among species. Some plants require long photoperiods (that is, length of day) to grow and develop, while other plants do better with shorter photoperiods. Photoperiods can be easily measured by the length of daylight at a site.

Soil

The word soil refers, in general, to the natural surface layer of the earth's crust in which plants grow. It is a porous medium, comprising minerals and organic materials. Living organisms, water, and gases are other constituents of soil. Whether climate or soil is more important in governing plant growth is immaterial, since both are necessary.

A site evaluation is normally incomplete without some kind of soil inventory, classification, or assessment. The evaluation of soil resources is conducted to determine the capacity of a particular site for a prescribed range improvement project or program, specifically in terms of supporting individual plant species or groups of plant species. More general information may be available from in-country files and experiment stations. Some international organizations, such as the Food and Agriculture Organization of the United Nations, can also provide general information (Dudal, 1970).

Evaluations of soil resources are made to provide adequate information for decision makers. Herein, the decision makers are concerned principally with the improvement of semiarid and arid rangelands. The kinds of decisions that these individuals will make must be known before a soil survey begins. Specific needs will largely determine which soil parameters should be measured and the procedures to be used in evaluating the soil resources.

It is beyond the scope of this report to describe the many techniques of conducting a soil evaluation. This information is available in numerous references; see, for example, Conant et al. (1983), Lutz and Chandler (1946), and the Soil Resources Inventory Group (1981). Instead, a "checklist" has been prepared to indicate many of the attributes that may be included in an evaluation of the soil resources on a site; each item is briefly discussed below. Obviously, the factors that are ultimately included in a particular soil survey must be those that relate to decisions made relevant to the particular range improvement project or program. Emphasis should be placed upon those factors that are "limiting" to the growth and development of the plant species.

Parent Material The underlying parent material from which soil develops has an important influence on the type of plants that a site will support. When the growth of an individual plant species is good on one site but poor on an adjacent site, investigation will often disclose that the two sites are characterized by geologic material of differing mineralogical composition and origin. In general, the soil is derived from the underlying rock. In some instances, however, the parent material may have been transported to the site by gravity, water, or wind.

Parent material, a descriptive parameter, is usually determined by field observations by a competent soil scientist. Geologic maps, if available, are also helpful in delineating the extent of soil that has been developed from a parent material.

Depth If soil depth is limited, the development of roots can be restricted. Soil depth is measured by exposing the soil profile and measuring the thickness of the separate layers. Many basic soil properties are characterized by horizon. The number of soil profiles taken at a site depends largely on the inherent variabilities of the individual properties.

Texture and Structure Two important physical properties of soil that greatly influence plant growth and development are texture and structure. Texture refers to the size and distribution of the soil particles (sand, silt, clay, and mixtures of them in various proportions); structure refers to the grouping of these particles into aggregates. Texture can affect and may restrict the development of roots, primarily through its influence on nutrient retention and aeration. Structure, which is most important in soils high in silt and clay particles, affects the percolation of water and air. The success of individual plant species in revegetation is dictated, in many respects, by texture and structure of the soil at a site.

Both texture and structure are descriptive measures, most commonly taken by horizon in the soil profile. Care must be exercised to ensure that samples are representative of the site.

Soil pH Different species of plants generally exhibit a preference for a degree of acidity or alcalinity in the soil, and have their own optimum pH values. Because pH may vary from one site to another, it should be included in a soil survey to maximize the returns from revegetative efforts. The pH of soil can be determined by using inexpensive but accurate field colorimetric sets.

Water-Holding Capacity As mentioned above, the survival and growth of plants is dependent on the availability of water in the soil. Waterholding capacity is a soil parameter of considerable utility. After saturated soil has been drained of gravitational water, it is (by definition) at field capacity. Field capacity is often determined in the laboratory, although approximations can also be made in the field by using a tensiometer. If desired, field capacity can be measured by horizon.

Organic Material The accumulation of dead organic material on a soil surface is significant to the "well-being" of plants in various ways. Organic material is, in time, a primary source of mineral nutrients. The organic increment of a soil profile is also a source of food for soil organisms that, in turn, are the chief causes of decay of the organic material; this process is critical in the nutrient cycles of a site. Organic material is colloidal, and thus, its waterholding capacity is relatively high.

Organic material content is minimal on many semiarid and arid lands. The sparse vegetation and year-round high temperatures favorable for rapid decomposition do not allow the accumulation of organic matter in appreciative amounts. The water-holding capacity of these soils is also frequently low. In general, the presence of organic litter may be quantified through visual inspection at a site, but differentiation into other compounds may not be possible except under laboratory conditions.

Salinity Salinity is often a constraint in revegetative activities. Saline and alkaline soils are commonly found in the valley bottoms of semiarid and arid lands. These soils create specific difficulties in selecting appropriate species for planting, and only plant species that are adapted to these sites should be used. Also, high levels of saline in soil reduces the amount of water available to plants and, therefore, can accentuate physiological drought.

Soil salinity is frequently measured with the aid of a Wheatstone bridge (an electrical device which measures conductivity). However, as is the case in surveying many soil attributes, these measurements are based on "point samples," which limit their extrapolation because of site variability.

Fertility Individual plant species have their own nutrient requirements for growth and development. When the soil lacks these nutrients, certain plant species may not be suitable for revegetation. In that case, it may be necessary to apply a fertilizer, although this practice may be uneconomical in an extensive revegetation project or program except for establishment. To the extent possible, the natural fertility of soil should be ascertained by chemical analyses. A practical approach to "measuring" soil fertility is to employ native plants as indicators of fertility ranges.

Knowledge of the ecosystem and successional cycles of a site is necessary for this technique, however. Quantitative expressions of soil fertility are obtained with soil-testing kits.

Soil Classification The classification of soil is an attempt to group soils into categories that, in general, are useful in understanding the dynamics of an ecosystem. It is based, regardless of the system, on an examination of the "typical" soils in an area. In the process of classification, a number of soil attributes may be considered, including (but not exclusively) many of those described above. Soil classification is time-consuming and generally expensive, but it can provide decision makers with necessary information for the effective planning of range improvement activities. Fortunately, many countries have soil survey departments that can furnish technical assistance for this purpose.

The selection of a soil classification system to be used in a resource evaluation program is an important consideration. For instance, the needs of a project with one objective may be met by a specificpurpose, site-specific soil classification, whereas an integrated rural development program requires the use of a general purpose soil classification. An example of the former is an irrigation project aimed at increasing the production of bananas. In this case, soil properties important to water management considerations must be used as differentiating criteria in the development of a specific purpose soil classification. On the other hand, a multifaceted rural development program requires a general-purpose soil classification to assess the suitability of soils for a variety of uses. In this case, soil classes must be defined by attributes relevant to a wide spectrum of management goals.

Several general-purpose soil classification schemes have been developed by different countries to meet their needs. As Smith (1963) noted, a soil classification scheme developed in a particular country is biased by the accidents of geology, climate, and the evolution of life in that country. Its application in other countries can be problematic.

The FAO/Unesco soil-classification system (Dudal, 1968) and the U.S Comprehensive Soil Classification System (Soil Survey Staff, 1975) are now used in many nonindustrialized countries (Conant et al., 1983). The FAO/Unesco system attempts to group the soils of the world. Because of the wide spectrum of soil-forming environments, groups in this system include considerable variability. On the other hand, soil taxonomy was developed to facilitate soil survey in the United States (Smith, 1963). To avoid ambiguity, soil classes are precisely delimited by chemical and morphological properties. The rigidity of class boundaries and the need for laboratory analysis hamper the successful application of soil taxonomy in nonindustrialized countries. Furthermore, since the current version of soil taxonomy was based primarily on soils from temperate regions, its use in tropical areas may be problematic.

In addition to the FAO/Unesco soil grouping and soil taxonomy, several other soil classification schemes are in use in nonindustrialized countries. The relationships and main features of several of these are outlined by Beinroth (1975), Buol et al. (1980), Butler (1980), Camargo and Palmieri (1979), Conant et al. (1983), Jacomine (1979), and The Soil Survey Staff (1975).

Landform and Relief

Characterizations of landform and relief are necessary to the evaluation of a site because of their influence on climate and soil conditions. In many instances, the relation of plant survival to landform and relief is very close. At a minimum, general landform and relief should be quantified at a macro level.

In general, an area should be divided into "warm" and "cool" sites on the basis of aspect and slope combinations. So-called warm sites in the northern hemisphere are oriented, in a clockwise direction, from southeast to northwest, while "cool" sites are oriented from northwest to southeast. Of course, this situation is reversed in the southern hemisphere. Within a particular aspect class at a given latitude, slope is important when orienting a site to the sun. More gradual and steeper slopes receive less intensive sunlight than do "intermediate" slopes; the hottest and often the driest sites are those that most directly face the sun on a summer day. The amount of solar radiation received on a site is closely related to other factors (for example, precipitation, temperature, and soil moisture) that, individually or collectively, influence the choice of species, establishment, and the growth of plants.

The position of a site on a slope can also determine the growth potential of an individual plant species. High, convex surfaces, which are frequently subject to wind erosion and weathering, tend to be drier and (in dry climates) warmer than is average for an area. Conversely, low, concave surfaces, on which soil tends to accumulate rather than erode, are generally moister and cooler than average. Midslopes are typically intermediate in these characteristics.

Knowledge of the terrain of a site may be helpful in selecting the most appropriate method of revegetation. For example, level to gently rolling lands are preferred in many instances because ground preparation, if necessary, can be more effectively accomplished with machinery at less cost. Investigation has shown that the cost of ground preparation rises sharply on slopes that exceed 20 percent and is generally uneconomical.

Measures of landform and relief of a site can be obtained from topographic maps, if they are available. On site, aspect is normally determined with a compass, and slope is measured with an Abney hand level (or pocket altimeter). Aspect and slope can be "integrated" into a single measure of site orientation through use of daily solar radiation values for explicit combinations of aspect, slope, and latitude (Buffo et al., 1972; Frank and Lee, 1966).

Water Resources

Range improvement projects or programs on semiarid and arid lands are highly dependent on the distribution and availability of water to me et the water requirements of individual plant and animal species. The seasonal availability of surface water resources must be inventoried in terms of surface flows and impoundments, and seeps and springs. Locations of existing wells and promising groundwater aquifers (for subsequent development) should also be studied. In general, estimates of potential yields and (as mentioned below) quality of water resources may be necessary in comprehensive range improvement.

Water quality, both physical and chemical, must be considered in the evaluation of a site if, as part of a revegetation effort, artificial watering is required. Individual plant species possess their own "tolerance" to the physical and chemical properties of water. Therefore, when water is to be applied, these properties should be known to maximize the benefits and minimize the detriments of the watering.

Sampling and analytical techniques of assessing water quality are numerous. However, to ensure high-quality results, a prerequisite to the extrapolation of water quality information, only "standardized" methods should be employed. These methods are detailed in Conant et al. (1983), Dunne and Leopold (1978), and Wisler and Brater (1965).

Biotic Components

Plants, animals, and humans comprise the biotic components of a site. The importance of these components and ways of measuring them are discussed below.

Plants

The native plants that are growing on a site, if any, can be helpful in describing the inherent productivity of the site and, from this knowledge, the chances for a successful range improvement activity. The occurrence of “key" plants can often be used to indicate site quality. Also, knowledge of the productivity levels of native plants can “index" levels of production that might be expected from subsequent range improvement activities. Observations of plants that can be important in the evaluation of a site include, but are not limited to, identification of the individual plant species (taxonomy), properties of the individual plant species (for example, chemical composition and particularly, the traditional uses of the plants which indicate important properties), groupings of the individual plant species into communities, and vegetation-soil-terrain relations.

Of course, interpretations of individual plants and communities of plants must be undertaken in light of the on-site land-use patterns. Use of plant resources as described above can be hampered by land management practices that result in excessive utilization of the plants on a site. Because previous and current land uses may tend to cloud the picture, the ecological impacts of these previous or existing land use patterns on the plant resources must be well known and thoroughly understood.

Plant Indicators Various key plants may be useful in analyzing the capacity of a site for range improvement. To a large extent, the presence, abundance, and size of these plants will often reflect the nature of the ecosystem of which they are a part and, therefore, may serve as indicators of site quality. However, the correlations between “key" plants and associated site quality, which are generally based on detailed ecological investigation, may not always be apparent. Effects of competition among individual plant species, events in the history of plant development (such as drought, fire, and outbreaks of insects), and land management practices can weaken a plant association to the point that it has little predictive value. Nevertheless, in many situations, site quality is sufficiently reflected by plant indicators to make use of the latter in an evaluation of a site for range improvement.

Sometimes, the occurrence of plant indicators is combined with abiotic components of the environment (for example, climate, soil, and topography) in an attempt to describe more accurately the quality of a site. The more factors that are taken into consideration, the better is the estimate of site quality and, consequently, the understanding of the potential of a site for improvement practices. Comprehensive reviews and comparisons of site evaluation, including its history, methods, and applications, have been prepared by Jones (1969) and Carmean (1975).

Productivity Levels Knowledge of the productivity levels (that is, amounts of plant material present) of plants growing on a site can provide insight into what might be expected from any range improvement practice. Information regarding the total production of all herbaceous plants, taking into account the loss of plant material to utilization, is often used as a "threshold" productivity value. In other words, improvement should be expected to exceed the existing productivity levels. If excessive utilization of the plants has occurred, the measures of existing production may be biased downward.

Volumetric measurements of plants are seldom made to quantify productivity levels. Instead, weights are used to measure the biomass of the plant material present. The weights of plants are most precisely obtained by the clipping of sample plots. But, since clipping is time-consuming and costly, a double sampling procedure is frequently employed to measure productivity on an extensive basis; weights of plants are estimated on all plots, with only a few plots clipped to derive a factor to correct the estimates, if necessary.

Whenever feasible, productivity levels should be obtained on the basis of individual plant species to allow subsequent groupings into plantform categories or grazing value classes for decision-making purposes.

Plant Cover In addition to the productivity or biomass available for utilization, the ability of the plant community to stabilize the site and arrest the soil erosion process should also be determined. Productivity information alone does not provide the manager with this knowledge. The percentage of the soil surface that is covered by plants, either only by the base of the plant (basal cover) or by all above-ground plant parts when viewed from above the canopy (canopy cover), indicates both the susceptibility of the site to erosion and the established dominance of one plant species over another.

Plant Number A plant community might be dominated, in terms of productivity and cover, by one or two plant species, the individuals of which are old and decadent. As these individuals die, they will be replaced by the same or new species. Data on number of plants of each species may give the land manager an indication of the health (vigor) and reproductive status of species in the community and, therefore, insight as to which species are likely to increase or decrease. Knowledge of this sort will guide the selection of the appropriate range improvement practice.

For more detailed information concerning techniques for vegetation analyses, the reader is referred to Conant et al. (1983), a publication prepared specifically for efforts in nonindustrialized countries.

Other Measurements and Observations To help in the selection of individual plant species for revegetation projects and programs, there may well be other kinds of on-site surveys or observations of plant resources that should be taken. Depending on the goals of the improvement practice, these may include growth forms and plant community structures (that is, vertical layerings); seasonal growth, development, and maturity patterns, including the differences among grasses and forbs, shrubs, and trees; and ecological conditions and trends (Pratt and Gwynne, 1977), as these parameters are influenced by successional cycles and degree of site deterioration.

Animals

Individually and collectively, animals have a major impact on the physical environments and the plant communities with which they are associated, and, as a result, can affect range improvement activities in diverse ways. Depending on the activity, these impacts can be beneficial, detrimental, or both. Some animals greatly influence the ecosystem processes that are basic requirements for plant growth and development, such as nutrient and water cycling.

Successional patterns are affected by other animals, by regulating competition, development, and productivity among individual plant species and communities of plants.

A major influence on the success of range improvement activities is the grazing activity of larger ruminant herbivores. However, both the positive and the negative roles that animals play in an ecosystem should be considered in a site evaluation.

Many semiarid and arid lands furnish habitats for wild animals and domestic livestock. Therefore, knowledge of animal types that occur on a site, their distribution and routes of migration, and their ownership or legal status can dictate, to some degree, the options for range improvement.

Animal Types All types of avian and terrestrial fauna (including soil biota) are part of an ecosystem. Difficulties arise, however, in defining the geographic boundaries when more-mobile animals are evaluated. In practice, ecosystems are commonly based on plant communities, soil classification units, or other abiotic features, or combinations thereof, and animals are then “incorporated” into the delineated ecosystems as consumers and secondary users. Mobile animals generally roam over several ecosystems.

Wild animals have varying effects on the ecosystem. Earthworms, arthropods, and ground-dwelling mammals play major roles in the decomposition of organic material. In their absence, the nutrient cycles of a site can be adversely disrupted. Birds are important agents of seed dispersal for many individual plant species. This dispersal activity can be beneficial or harmful to reproductive strategies. Mammals, especially rodents, can also be important agents of seed dispersal in many plant communities.

The grazing activities of the larger ruminant herbivores, both wild species and domestic livestock, have already been mentioned, and are covered in more detail in chapter 6. Grazing is commonly considered destructive, although it can benefit the desired vegetation on a site by removing competitive plants that otherwise may use limiting water and nutrient resources. Grazing activities also prevent the buildup of coarse, unpalatable plant parts and stimulate the growth and tillering of more plant materials.

Techniques of enumerating animal types and their respective numbers, including the censusing or sampling of animal populations, are described in Child et al. (1984), Conant et al. (1983), and Schemnitz (1980).

Distribution and Migration Patterns In addition to knowing what types of animals occur, knowledge of their distribution and patterns of migration can also be important in site evaluation. Uniformly distributed animal populations generally tend to exert uniform effects on a site. On the other hand, a population of animals that is unevenly distributed will frequently have uneven effects upon a site (for example, animals clustered around a wellhead). The distribution of animals is also influenced by their migratory patterns. In general, migration (whether seasonal, yearly, or indeterminate in response to unknown stimuli) can result in cycles of impacts that should be known when planning a range improvement program.

Information regarding the distribution of animals can often be obtained while their kind and number are being enumerated. Migratory patterns, which are descriptive measures, can be determined only through repeated observations of the animals on a site.

Ownership Status The ownership of animals can be important to a range improvement activity, particularly in situations in which the control of the animals is necessary to the success of the venture. In general, the ownership of wild animals, if specified by law, lies with the state, which may assume responsibility for their regulation. However, domestic livestock are often privately owned by individuals or groups of individuals that operate in a cooperative. The ownership of animals must be established, and the responsible parties contacted and their cooperation obtained, if manipulation of the animal populations is considered necessary to ensure the success of an improvement project or program.

Humans

It is necessary to assemble and analyze what is known about the human users of the land and, of equal importance, what values people attach to the natural resources that will be affected by a range improvement activity. Deficiencies of information in this area can, and in most cases do, constrain the effectiveness of a project or program. Serious conflicts often exist between traditional land management practices and what might be proposed in a range improvement plan. Therefore, it is imperative that proponents of range improvement understand the people who will be affected, and the reasons why the people do what they do (see National Research Council, 1986).

Information regarding human activities, land use in the area of concern, population densities and community structures, and the migration of families and family groups is a minimum baseline for the evaluation of humans. Rural sociologists, ethnologists, cultural geographers, and ethnic botanists, all working at the local level, should be involved in this work.

Integrated evaluations

Two basic approaches are employed in the evaluation of a site, regardless of the purpose: an integrated approach and a component approach, as explained in chapter 4. Abiotic components and biotic components that are important in evaluating a site for range improvement have been discussed in the preceding sections, component by component. Most on-site surveys and observations of natural resources are based on a component approach, although the individual components being evaluated are not necessarily considered in isolation. Within a systems framework, the components that are related to the improvement of a site must be evaluated in an integrated manner. By doing so, all of the elements of an ecosystem, both abiotic and biotic, will be studied to form as complete a picture as possible of a site being considered for improvement.

One final point: many site evaluations fail to include a provision to monitor the changes in an ecosystem that could, subsequently, have an influence on the success of a range improvement effort. Therefore, to the extent possible, monitoring should be provided to be sure that temporal changes, both positive and negative, are recorded and identified for possible changes in past project management as well as for use in future project planning.

In the preceding pages, much has been said about the various factors that need to be measured and evaluated. How these components are used in evaluation has not been discussed. A computer model is not generally the answer. Some limits may be needed to delineate the range of acceptable conditions.

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Grazing management

In recent years, there has been renewed interest in indigenous management systems, such as the hema system of the Near East (see case study 9). Such systems represented highly sophisticated adaptations to the peculiarities of particular environmental settings. The breakdown of these systems, often as a result of disorienting socioeconomic change during the colonial era, has resulted in widespread environmental degradation. While the principles upon which these systems were based are still valid, changing environmental, socioeconomic, and political conditions present new challenges. In many areas of the world, the most promising approach to rangeland improvement is to complement the adaptations of local populations with relevant experience from analogous areas elsewhere. This chapter discusses grazing management from a Western, technical perspective.

To meet the needs of forage-fed livestock and provide the other products and services from rangelands, these lands must be managed wisely. If they are mismanaged to the extent that plants fail to provide sufficient soil cover, the species composition of the plant communities changes, reducing productivity and increasing soil erosion. Continued abuses can result in severe soil degradation. As indicated in the previous chapter, this does not imply, however, that all grazing is destructive. Some native plant communities have evolved over thousands of years under grazing by native animals.

Not all major plant species have evolved under grazing pressure.

Species that are not adapted climatically should not be considered important components of the range ecosystems. Plants must be adapted for grazing or browsing by animals and for soil protection.

The value of all plants growing in an area must be considered. Even small populations of a few species may contribute much to animal performance during a brief but critical part of the year.

Range management involves both range improvement and grazing management practices. Range improvement generally has greater potential than grazing management for increasing production. Such practices as brush management, revegetation, and fertilization can increase range forage yields as much as tenfold. Manipulation of grazing time and intensity, on the other hand, usually results in relatively minor changes in range productivity.

Rangeland revegetation by livestock manipulation alone is not as dramatic as mechanical revegetation, and it may take more time. On the other hand, it will likely be much less expensive and may be more in harmony with local cultures. Livestock manipulation may involve protection of areas from grazing, deferred grazing, seasonal grazing, rotation grazing, stocking rates, or intensity of grazing, or various combinations of these approaches.

Grazing management concepts

The application of ecological principles to range science often means maintaining or improving native stands of vegetation through grazing management. In addition, range managers may use a combination of extensive and intensive practices; for example, brush management combined with a grazing system, or revegetation and fertilization combined with a grazing system. A range manager can select the degree of intensity for a unit of rangeland depending on the potential of the sites within that unit; economic, social, and political factors; and available technology. Rangelands can be managed for various objectives, attempting to achieve a balance among management and social, economic, and environmental concerns.

Range managers must be flexible and innovative when planning operations on a range unit. Practices successful on one range unit may be less so on the next, or even unsuccessful on a unit nearby. No grazing scheme will eliminate the need to practice all economically appropriate range management techniques. No practice will produce the desired results if the range manager does not understand and believe in the principles involved, monitor the performance of units and animals, and adjust schedules and livestock numbers to changing conditions.

Forage production on rangelands, though controlled to a large extent by range site characteristics, is critically tied to the health of the root system in perennial forages and to seed production in annual forages. Consequently, grazing strategies must be developed to maintain a healthy root system in perennial forages and an optimal seed yield in annual forages. Specific grazing practices to maintain productivity will necessarily vary with the limitations of the site an d weather during the growing season. Roots can successfully grow and support a forage crop under grazing when the intensity and time of use is properly controlled. Individual plants need to grow, to photosynthesize, and to replace damaged or senescent tissue every year. This can be accomplished by closing an area to grazing during the growing season, by stocking lightly enough that the livestock remove forage at a rate slower than the growth rate of the forage, or by rotating use so that forages are ungrazed during critical periods of the growing season. Any of these approaches can be successful when the specific growth patterns of the forages are known or can be estimated.

Since most rangelands are made up of a complex of species, grazing must consider availability and palatability of the vegetation produced each year. Livestock will not graze all individual plant species uniformly unless the pasture is overgrazed or grazing is carefully designed to produce a uniform pattern of grazing that provides for sufficient vigor to produce the next crop. Within a given site, different plant species will maximize their growth at different times of the growing season. As the plant community develops, there is a continual change in relative proportions of different plants and, therefore, a continually changing availability of forages. Along with the changes in availability, there are changes in palatability among species or changes in palatability related to the growth stages of the constituent plants.

If grazing is unmanaged or managed without consideration of the dynamic nature of the plant community, some forages will be used heavily while others are lightly used or not used at all during the period when interspecific competition is critical. Desirable forages that consistently are at a disadvantage because of differential grazing will lose to the more competitive plants. This will change, and usually reduce, the productivity of the range site. If grazing is designed to take advantage of the natural community dynamics of a range site,

the loss of desirable forages can be prevented by manipulation of the time and intensity of grazing. Grazing may need to be varied within the growing season in some cases, among sequential growing seasons in other cases, or in a combination to most effectively match the livestock with the forage.

Rangeland productivity may decline with grazing unless the practices that reflect certain principles are followed. One of the main principles of grazing management concerns the duration of time that animals are allowed to graze a given area and the timing of this grazing to critical stages of vegetation growth. A second considers the degree of uniformity of use that plants receive as influenced by an even distribution of grazing animals across a given area. A third involves the type of livestock grazed as a means of manipulating plant communities. The most sensitive, and thus the last, main principle that should be addressed, particularly on communal grazing lands, relates to the numbers of animals grazing an area. All of these principles must be applied to one degree or another when prescribing a grazing management scheme.

Time of grazing

The primary purpose of range management is to prevent excessive grazing. This is especially important during the growing season in order to increase the vigor and productivity of existing plants and, eventually, to improve species composition. An alternative to heavy grazing to obtain use of less desirable plants is to graze a unit during that time of year when less desirable species are more palatable than preferred plants. In South Africa, it was found that the longer the period of grazing, the lower the carrying capacity and the more adverse the effect upon the associated rangelands.

Nutritional quality of forage is highest early in the growing season and declines as the plants mature. Grasses, forbs, and browse are similar in quality in the earliest growth stages. As plants mature, substantial structural changes occur that usually decrease palatability and always reduce nutritional quality. When the seasonal changes are complete, grasses remain good and are often adequate sources of energy for ruminants, whereas shrubs (or browse) are deficient in energy but usually adequate in protein and important vitamins and minerals (many are deep-rooted legumes). Forbs vary considerably but tend to be intermediate in nutritional quality, although they are often unavailable because of weathering and disintegration of leaf tissues. In the dormant season, a forage supply on the range that consists of mature grasses and shrubs will more closely meet livestock nutrient requirements than will a pure stand of either forage class.

The seasonal forage quality and palatability can be managed by grazing programs to some degree. Maturity results from the natural behavior of range plants with respect to the annual moisture and temperature cycle. When a plant is grazed in the growing season, the annual growth cycle will start over if there is sufficient soil moisture to permit regrowth. If enough of the annual evaporation, transpiration, and precipitation cycle has been completed, the regrowth will not mature and thus will cure before the quality has declined. The magnitude of this response will depend on the timing of grazing. On many range sites, it is possible to condition the forage by grazing in the growing season to yield a nutritionally adequate and palatable forage supply for the dormant season with respect to important macronutrients.

Controlling the time of grazing is as important as defining the proper stocking rate and, in fact, may control the stocking rate.

Grazing a perennial grass during the early stages of seed development will invariably stress the plant, and a period to grow without grazing will be required if the plant is to recover from that stress. Conversely, grazing a mature perennial grass offers little stress to the plant. A higher stocking rate can be supported on a perennial grass range grazed largely in the dormant season than if the same range were grazed largely in the nondormant season, though in the dormant season a variety of nutrients would need to be considered for supplementation.

As previously mentioned, grazing can be used to condition forages for use later in the year. In these situations, the effect of timing of grazing may reduce yield while improving quality. The stress on the vegetation caused by the timing of grazing can be acceptable when incorporated into future plans for utilization of the specific pasture. When plants or animals are stressed, their productivity will decline.

In most range ecosystems, the desirable ecologically stable climax species are long-lived perennial plants. Many of these plants are poor seed producers and do not reproduce readily from seed. If these desirable species are depleted by overgrazing or drought, it can be difficult or even impossible to encourage their recovery by manipulating grazing. In a dominantly perennial plant community, however, grazing use can be adjusted to encourage seed formation if seed production is important for reproduction. Similarly, vegetative reproduction of certain species can be encouraged by manipulating the time of grazing.

Desirable perennial plants produced on rangeland must be used moderately during the growing season; thus the old guideline: use half and leave half. Where additional soil protection is required, herbage utilization should not exceed 40 percent. Heavy use of perennial forage plants, followed by prolonged drought, can result in the death of many desirable plants. On the other hand, usage greater than 50 percent is beneficial under some conditions. Ephemerals, often annual plants, generally are grazed by animals extensively when they are available. The forage crop may vary greatly from one time to another because of precipitation differences. It is not unusual for the annual forage crop on rangeland to vary between 50 and 150 percent of its average productivity.

Distribution of grazing

Proper grazing use of forage plants most often calls for an even distribution of livestock. In the large range units, prevalent in most arid and semiarid areas, it is possible to find serious overgrazing near watering points (figure 6-1) and no use of forage in other portions of the unit. Animal distribution can be improved by (1) increasing the number of watering points (though this must be done carefully, since increasing the number of waterpoints increases the number of cattle and can lead to overgrazing), (2) establishing salting and supplemental feeding areas 1-3 km from watering points, (3) using more fencing or herding, (4) building trails, (5) fertilizing selectively, and (6) using a different class of livestock. Any practice that improves animal distribution will increase range productivity.

Provided that water and protection are available throughout the grazing areas, traditional systems of herding found in many tropical and subtropical countries largely overcome the distribution problem and have usually evolved to use the area for optimum productivity.

Type of animal grazing

Another method of favoring the desirable forage species for one type of animal is to use different kinds of livestock or wildlife to reduce temporarily the less desirable plants.

Animal species use plants in significantly different ways. For example, camels can eat more woody shrubs (figure 6-2) than any other domestic species, roam farther from water to forage, 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 (figure 6-3), but they cannot move nearly as far from water as can the camel. Cattle (figure 6-4) and sheep prefer grass. Sheep, however, will eat more tender shrubby materials and have a preference for forbs (figure 6-5). 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.

Because of their food preferences, animals may also be used to some extent to control the composition of the vegetation. For example, goats and water buffalo 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 wildebeest; cattle are grazed in southern Brazil, Uruguay, and adjacent parts of Argentina in order to prepare the rangeland for use by sheep.

Number of animals grazing

The concept of reducing the number of animals owned is very threatening where livelihood and proper herd management, as well as prestige, depend upon the size of one's herd. A more acceptable approach might be to regulate the intensity of grazing wherein time of grazing is more controlled than the number of animals.

Grazing intensity is measured in animal unit months (AUM), which is the livestock concentration per unit area (stocking rate) multiplied by the proportion of time that a unit or portion of a unit is grazed. The intensity of grazing on rangeland forages will always be a pivotal consideration in developing a grazing program. There is, of necessity, a limit to the number of animals that a given range will support. Management will have a major influence on stocking rates, which will be higher as management integrates the biological and economic considerations to provide the optimum plan for a specific range unit. Stocking rates that exceed the carrying capacity of the range may increase livestock offtake in the short term but in a very few years will lead to declines in the land's productivity and, therefore, substantial decreases in livestock (figure 6-6).

To achieve maximum production per unit area, liveweight gain per animal is reduced. High production, both per animal and per unit area, can be achieved by varying the stocking rate during the grazing season. Relationships between intensity of grazing and livestock production are shown in figure 6-7. This relationship, described by Heady (1975) as he adapted it from Mott (1960) and Bement (1969), has been applied to the Somalia case (Bement, 1981). Stocking rate is related to product per animal and product per hectare.

Individual animal grazing and gain per hectare are shown with increasing amounts of ungrazed or available forage on a conceptual basis. The left side of the figure indicates insufficient feed for animal gains. With increasing feed, animals gain in weight, reaching to a maximum 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 provides a flexible and practical procedure for determining stocking rates in response to changing forage supplies.

This relationship indicates that individual animal gains are maximized at the lowest stocking rates. As intensity of stocking increases, the gain of individuals declines while the yield per hectare increases. At the point of optimum productivity, the individual animal gains are still high and the yield per hectare is near, but not at, maximum. Further increases in stocking result in deterioration of the range, which eventually decreases the ability of the range to produce. As grazing continues in the overgrazed portion of the range, productivity declines per hectare. If this results in significant soil loss, the original productivity may never be regained.

Grazing management planning

Consideration of the overall management plan, including both range improvements and the grazing scheme, is critical. All practices that are beneficial and economical should be integrated into the management plan.

Range units feature varying characteristics and must be managed accordingly. They may differ in their improvements, such as fencing and water developments, the proportion of various soils and types of vegetation, the numbers and kinds of livestock and wildlife supported, and the recreational opportunities they provide. Cultural, economic, or political conditions may determine the degree of management applied. As conditions change or technology improves, the range manager may decide to modify management objectives.

Wide fluctuations in the forage crop, in both the amount present and the kind of plants that are prominent, are common. When range operators adopt a grazing scheme, they may allow for flexibility as to time of grazing and deferral from grazing as well as the number of livestock involved. This flexibility may be the difference between success and failure in the grazing scheme. Both plant and animal requirements must be considered. For example, some range units may be manipulated to furnish highly nutritious forage during a period when livestock need greater nutrition. The critical growth stage of plants also varies over time because of weather conditions. Because of grazing history and weather conditions, it may be more important to defer grazing in some periods than in others. Range units should be grazed when the key plants are damaged least by grazing and when the forage best meets the nutritional requirements of the animals. In many cases, this means grazing in no set or predetermined sequence.

Many indigenous pastoral systems in Africa and Asia provide excellent examples of flexible response to changing rangeland conditions. A description of the pre-Colonial management system centered in the Masina region of Mali, prepared by Malian range scientist M.-L. Ba, follows this chapter.

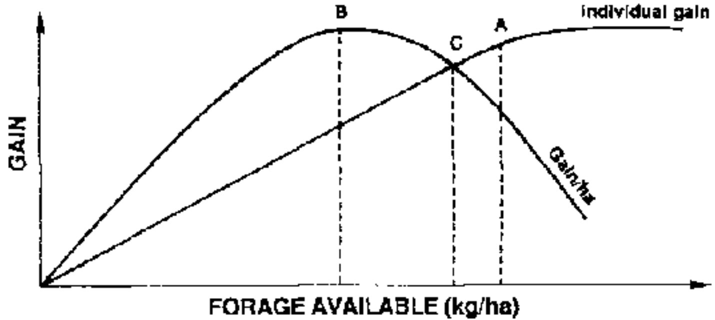

FIGURE 6-7 Relationships between intensity of grazing (forage available) and livestock production. (Source: Bement, 1981)

Grazing schemes should also be tailored to conform to a variety of vegetation types, soil types, physical facilities, and herd-management plans. There may be considerable variation among ranch operations in the specific details of operating a certain grazing scheme. In some instances, it may be desirable to use a particular grazing system to attain a certain measure of improvement and then change to a different system for maximum net returns while maintaining the resource. South African research suggests that the advantage of multiunit schemes is their greater flexibility in permitting the range manager to alter the grazing scheme as the precipitation varies and as the specific requirements of each unit dictate.

Livestock control is absolutely the most important factor in successfully managing grazing on rangelands. If grazing is not controlled to meet the objectives and requirements of the grazing plan, the plan will fail. Livestock control is usually carefully organized by farmers and herders in tropical and subtropical countries. In many areas, the extensive overgrazing that dominates range use results from a decision to graze during a given time in a given place, not from a lack of livestock control. Consequently, grazing controls within planning specifications can only be accomplished through joint decisions of herders, livestock owners, range managers, and government officials. The key to livestock control is, of course, an understanding of costs and benefits of control.

Grazing management systems

Grazing systems or methods can help improve distribution irregularities for widely ranging livestock, can improve rangeland forage conditions by protecting plants during critical growth periods, and can improve livestock performance by ensuring that plants are utilized at the best times and sometimes even improving their quality for livestock late in the grazing season.

Managing the range forage resource becomes a science of balancing the plants, their requirements for growth, and the needs of animals for nutrients that are best supplied by immature plant tissues. Grazing programs that maximize animal benefits are most stressful to plants, and those that maximize plant growth are least beneficial to animals. Design of grazing management programs must consider the long-term maintenance requirements of the forage base and recognize that it may not be possible to meet all of the nutritional requirements of livestock from the range. A grazing program can, with necessary nutritional supplementation, be designed for any range to be productive of the right kind and number of livestock and at less cost than production systems based on other kinds of forages.

Most grazing programs will need to be supported by a variety of developments. Holding pens and corrals are necessary to confine livestock for animal husbandry programs (figure 6-8). These structures can be easily constructed of native brush or new materials such as nylon mesh fences that are easily portable. Dipping vats may be required to control parasites (figure 6-9); portable vats are commonly used because they increase management flexibility. Water structures such as wells, catchments, or springs are necessary (figure 6-10), and these can be placed in each pasture or at a central facility if animals are close-herded. Fences are required to confine animals to specific pastures if herders are not used in a grazing system. If land control and management do not exist, however, fencing is a costly and futile exercise. Finally, access is needed for transportation of supplies and products.

Use of a grazing system may alter the species composition of a plant community. An increase in palatable plant species may permit increased use of the range resource. Nevertheless, the benefits obtained from improved grazing management practices are relatively few compared with those possible from manipulative range improvements.

Long-duration grazing refers to continuous grazing, where livestock are left in one pasture for the full grazing season or for periods of several months to more than a year. The periods of deferment from grazing may also extend from several months to more than a year. Single herds or several herds of animals may be involved. Conversely, short-duration grazing involves one or a few herds of animals that are moved to a new unit every 2 to 28 days. Deferment from grazing extends from 42 to 180 days. Both grazing and deferment periods are important.

Long-duration grazing often requires a minimum outlay of capital for fence and water developments. Management inputs are also relatively minor because decisions on livestock numbers and when to move the animals to another unit are not critical so long as the permanent range resources, both plants and soils, are not irreversibly damaged.

Short-duration grazing, on the other hand, may require a larger outlay of capital for fence and water developments. Decisions on movement of livestock are critical because young plants should only be grazed once before receiving some deferment from grazing. Therefore, both the risk and management requirements are greater with the more intensive shortduration grazing. However, higher effort management inputs, whether they involve a grazing system or an improvement practice, do not guarantee higher returns to the operator.

Continuous, year-long grazing in perennial plant communities can be successful for a number of reasons:

· Herbage production depends primarily on summer rainfall, and monthly summer herbage production can vary tremendously.
· Most species are grazed by cattle at one time or another.
. Many "increaser" species, those that increase in number under grazing pressure because they are often less palatable and are not selected as frequently by the grazing animal even though they are excellent plants for grazing, may be productive under certain environmental conditions.
· Cattle compete with natural losses of forages, and with other forage consumers such as rabbits, rodents, and insects.
. Young forage and regrowth forage are more palatable and more nutritious than mature forage.
· Grazed plants save soil water for later green growth.
. Favorable growing seasons, combined with proper grazing management, allow ranges to recover a desirable species composition.

The success of year-long continuous grazing in perennial plant communities is further enhanced because grazing is light during the growing season, and lighter stocking per unit area means less soil compaction by livestock when the soil is wet.

Some of these same reasons could also be attributed to rotational schemes. Under rotation systems of grazing on perennial rangelands, units have sustained increased numbers of livestock and have shown greater improvements in range condition than have units grazed continuously on a year-long basis at various stocking rates. An advantage of deferred rotation is the infrequency of livestock movement required. Under the system, livestock must adjust to the new forage of each grazing unit only once every grazing sesson.

A rotation system using as many as 16 units, each grazed 2 weeks or less by 1 or 2 herds, has been studied in South Africa and Zimbabwe. Livestock are not moved at any set time, nor are the units necessarily stocked in sequence. When plants are growing rapidly, the livestock are moved frequently, perhaps as often as every 5 days, to prevent injury to plants. When the plants are dormant, livestock movement is determined by the nutritional requirements of the animals.

An evaluation of grazing systems in southern Africa concluded that the following principles are important:

· Slow rotation systems do not eliminate selective grazing.
· In a 16-unit, high-intensity, low-frequency system, 12 units are grazed once for about a 2-week period every 6 months, and the 4 other units can be used as reserve grazing in dry years or given a full year's rest in years of average precipitation.
· High-intensity, low-frequency grazing is designed primarily to combine sufficient rest with efficient use to permit rapid restoration of denuded rangelands. There is less advantage to using this system on rangelands in good condition.
· Range restoration may be retarded and greater abuse may occur if stocking increases more rapidly than indicated by herbage production.
· With variable precipitation, no system can eliminate selective

grazing if set grazing periods and stocking rates are maintained, but high-intensity, low-frequency grazing reduces selective grazing.

· High-intensity, low-frequency grazing, because it is an intensive system, may require more labor, fencing, and water development, but the relatively high capital investment required to implement this grazing may be justified by the resulting increased carrying capacity.

Short-duration grazing or "cell" grazing uses some of these same principles. Cell grazing, however, requires even shorter periods of livestock grazing when range plants are actively growing. This is a one-herd system wherein the units can be (but need not be) laid out somewhat like a wagon wheel. In the center are pens and watering devices. Livestock are moved to the next unit to be grazed by opening the gate, which is located at the hub, and letting the livestock move themselves. Frequent movement among units prevents livestock from abusing individual plants.

All of these grazing systems and approaches have merit and all have been successful. On the other hand, all have failed when applied without concern for either plant or animal production requirements. In the final analysis, a specific range unit will produce most economically when all its unique characteristics are specifically considered. Prescription grazing to adapt grazing use to the site, to the needs of the people, to emergencies like drought, to market demands and all the other factors that affect the ecosystem and its use will result in protection and stability of the investment in the range and in the livestock. Only when grazing is managed by wellthought-out prescriptions for each grazing unit can the range manager be considered successful.

Livestock management

To achieve the livestock benefits from any grazing program, a workable program of animal husbandry must be in place. This includes animal health to prevent and cure disesses and parasite problems. Many tropical and subtropical countries have national campaigns to provide inoculations for endemic diseases and to provide advice on animal husbandry to the farmers and herders.

In planning the grazing use of the rangeland, one must consider the total annual nutritional needs of the herds with respect to lambing or calving seasons if animal reproduction is attempted throughout the year. The availability of sufficient quality and quantity of feed will dictate the probable success in livestock production. In many countries, the structure of the herd includes lactating and dry females, young growing animals, and mature animals. This is a normal situation since the livestock may be the "bank," and the offtake is marketed throughout the year. A lactating animal requires

a more nutritious diet than does a dry animal. If the herd is largely in the lactation production phase or, conversely, in the maintenance phase of the animal production cycle, the needs for nutrients from rangeland can be reasonably estimated. Herds that consist of growing, dry, and lactating animals should be fed according to the needs of the growing animals, unless special supplementation can be provided to those with the greatest nutrient demand. It is generally agreed that the animals with highest nutrient demand set the base nutritional requirement of the herd. In tropical and subtropical countries, however, the demand for quantity of forage is so great that little attention is paid to quality. A range manager who can find a way to upgrade the diet quality in growing or lactating animals could greatly increase productivity.

The range probably cannot provide the quantity or balance of nutrients during the entire year. If animals are fed when rangeland forage is deficient, then a grazing program should be developed to complement the feeding period. It may be necessary to provide only a portion of the nutrients during part of the year, and feeding can be replaced with supplementation that can bring the animal's nutritional level up to minimum requirements. Supplementation will be less costly than feeding and, when correctly used, will provide for excellent livestock performance on ranges that without supplementation cannot meet the minimal needs of the livestock.

Supplements can be worth many times their cost since they add what is needed to provide a correctly balanced diet, but supplementation is not a normal practice in most countries because of the comparatively high cost of desirable supplements. Furthermore, in remote areas, the cost of transportation of supplements to the herds is often prohibitive.

Since rangelands by their nature exist in areas with variable and extreme climates, a grazing program must have some plans for the expected but unpredictable droughts or storms. Forage reserves can be of utmost importance over the long term. Excellent use of shrubs and cacti is being made in many countries where the grazing demands exceed supply in extreme years. Forage reserves can prevent catastrophic losses if they are predictably planned for and used (figure 6-11). Although some use of forage reserves during normal years may be appropriate, it is critical that they be sufficient to ameliorate the forage losses that are sure to come to the semiarid and arid rangelands during drought. Many forage reserves are considered a luxury, since in many countries demand exceeds supply of forage in normal years. The hema system of North Africa and the Middle East

is a management strategy from previous centuries that still has merit for maintaining forage reserves for the expected drought years.

The herima system in Mali

The herima system is a variant of the hema system. It was introduced into the Masina Region of Mali in the 1820s by the Pulo cleric, Shehu Hamadu. The system is belived to have been derived from management systems established earlier in the Sokoto Region of Nigeria. The herima system was installed to:

· Regulate the use of the upland rangelands;
· Reduce animal-disease hazards very common in the swampy lowland areas; and
· Reduce conflicts between farmers and pastoralists.

The problems of the Masina Region have not changed greatly since the last century. Every year, more than 20,000 km^2 of land associated with the Inland Delta of the Niger River are temporarily

flooded and, as a result, the lowlands can support livestock only during periods when the swamps dry out. Infestation by various parasites and insects associated with the swampy conditions is a major cause of animal loss. The reduction of grazing areas during the period of inundation prompted overgrazing around villages. The insecurity of livestock herds outside the Inland Delta Region during the wet season, from July to November, had increased this deterioration of rangelands. Since the Inland Delta Region had great potential for rice cultivation, many conflicts occurred between farmers and pastoralists.

Shebu Hamadu developed the herima system as a strategy to solve a number of problems in his kingdom. There are several characteristics of the herima system. For example:

· Grazing zones were allocated for milch cows and were placed under the control of the community.
· Large grazing areas were allocated for use by dry herds, which come from everywhere.
· Transhumance was established to reduce disease hazards. This was possible only when Shehu Hamadu organized troops to protect pastoralists in regions not controlled by the kingdom of Masina.
· Rules were formulated to regulate the use of the rangelands and reduce conflicts.

The herima system was readily accepted because it was sanctioned by Islam, and Shehu Hamadu ruled his country according to the tenets of the Qur'an and the Hades. Some of the results of the herima system can be seen even today. Among them are:

· Respect for the organizational structures developed by Shebu Hamadu endures because these structures have religious support and the organization responds to the needs of the people in the area.

· A high-intensity land use pattern is in operation that includes the entire range of available resources.
· The calendar for the use of rangelands and the migratory routes established in the time of the Dina (herima) are still respected.
· A strong sense of ownership has developed among pastoralists who control the use of their communal herimas. Pastoralists also are in charge of improving these lands.
· Land is allocated for the production of rice, which is the major staple food in the Inland Delta Region.

Pastoralists living in the Inland Delta Region consider the herima system as essential for the use of the resources, and are strongly concerned with its gradual deterioration, which has resulted from several factors:

· Livestock build-up both within and outside of the Inland Delta Region as a result of the recent progress in disease control;
· The government policy of abolishing the right of ownership for the grazing lands, which allowed pastoralists who were strangers to the

areas not to respect the system and even use areas reserved for milch cows;

· The development of nonintegrated projects that give higher priority to rice production and thus decrease the area designated for grazing and the migratory route (resulting in conflicts between pastoralists and peasants);

· The deterioration of unflooded rangelands surrounding the Inland Delta Region, which reduces the animal waiting period before entering the region upon returning from the Sahel; and

· The 1968 drought, which substantially reduced the forage potential of the flooded region. As a result, many pastoralists left their traditional grazing areas.

In summary, the herima system can be considered to be an effective system for the natural resources of this area. Its success can be explained by its relevance to the social, religious, and environmental systems of the area.

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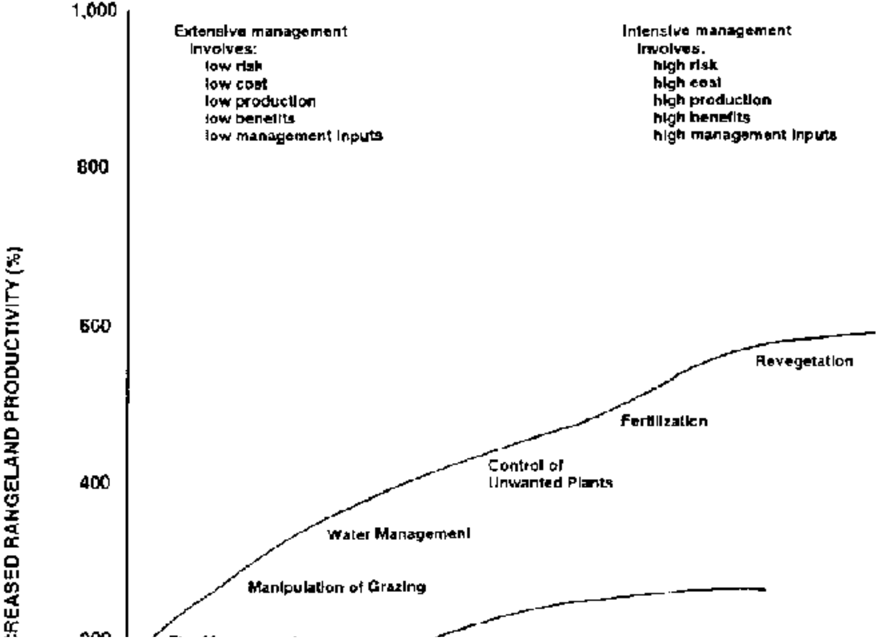
Rehabilitation techniques

Establishing plants on the range

It may be useful to consider the practices used in range management in terms of the relationships shown in figure 7-1. By so doing, levels of range productivity can be seen as functions of environmental, cultural, social, and political factors, as well as the availability of technology. It is important to understand these factors when determining effective approaches to range rehabilitation.

Extensive Practices

Range rehabilitation techniques vary greatly. Examples of extensive practices for rangeland management are the manipulation of grazing and the use of fire. These practices may require fencing, water supply development, and/or fire lines, but they generally require little management and do not risk the loss of the existing vegetative cover (as do some of the more intensive manipulative practices). Extensive practices are low cost, but opportunities to increase production are correspondingly limited. Other practices, such as water management, require a higher level of input than the manipulation of grazing or the use of fire, and are, therefore, intermediate between extensive and intensive practices.


1,000
800
600
400
REASED RANGELAND PRODUCTIVITY (%)
Extensive management involves:
low risk
low cost
low production
low benefits
low management inputs
Intensive management involves.
high risk
high cost
high production
high benefits
high management inputs
Revegetation
Fertilization
Control of Unwanted Plants
Water Management
Manipulation of Grazing

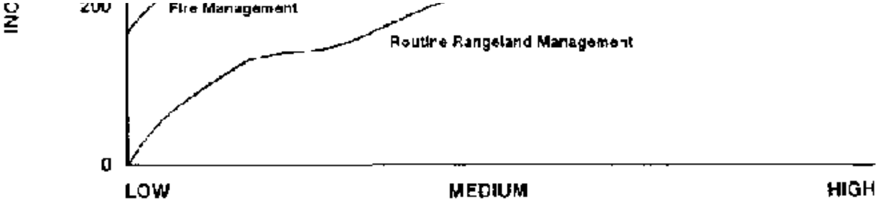


FIGURE 7-1 As site potential improves, the opportunities for increasing production are enhanced. By application of range improvement practices under intensive management, productivity can be significantly increased.

Intensive Practices

Drastic manipulations of range ecosystems are sometimes necessary. The use of intensive practices to control unwanted plants and to revegetate with desirable plants may be necessary because of the invasion of unwanted plants, the effects of severe droughts, past abuses by foraging livestock and humans seeking fuelwood, or the desire to change botanical composition to increase productivity on all or part of the range. The risks in using plant control or revegetation are high because even if attention is given to every detail, the practices may not have the desired effects. A thorough understanding of the range ecosystem and factors of production, as well as a commitment to high management inputs, is required if these risky, costly practices are employed. During the planning phase of intensive range rehabilitation programs, site potential must be carefully assessed.

Subsequent consideration might be given to the use of plant species from other locations in the world that may be more productive or better able to meet a particular requirement than the plants currently growing on the site. Generally, control of unwanted plants, revegetation, and fertilization are intensive practices for rangelands.

Combined Practices

Few, if any, land managers use intensive practices exclusively on a unit of rangeland. Rather, intensive and extensive practices are combined. To increase plant production and soil protection, each unit of rangeland must be managed to maximize economic, political, and social factors while maintaining or improving the basic resource. For example, in the Northern Great Plains of Canada and the United States, this may mean seeding part of the range unit with Russian wildrye Psathyrostachys juncea) and standard crested wheatgrass (Agropyron desertorum), and using nitrogen fertilizer on both native and introduced species. In portions of the Northern Plains, the best practices may include judicious burning of some native rangeland areas and plowing up the native sod on some of the better sites and seeding wheat for forage, or for forage and grain.

On the semiarid southern Great Plains of the United States and the associated grasslands of Mexico, a useful strategy may include seeding weeping lovegrass (Eragrostis curvula), side-oats grama (Bouteloua curtipendula), common wheat (Triticum aestivum), and Sudan grass (Sorghum sudanense). In the arid portions of the southwestern United States and northern Mexico, efforts to increase range productivity sometimes include the control of mesquite (Prosopis spp.) and tarbush (Flourensia cernua), and seeding with Lehmann lovegrass (Eragrostis lehmanniana) and Boer lovegrass (E. chloromelas), and fourwing saltbush (Atriplex canescens). On some rangelands dominated by big sagebrush (Artemisia tridentata), control of the sagebrush and seeding with fairway crested wheatgrass (Agropyron cristatum) results in greater productivity and soil stability than would be obtained without sagebrush control and seeding. In some instances, composition of plant species may be manipulated to improve wildlife habitat, while at the same time maintaining or improving livestock production. Suitable proportions of trees, shrubs, and grasses in tropical and subtropical rangelands would, of course, be determined by the characteristics of the environmental system considered, as well as by the specific requirements of the forma of livestock being managed. For example, trees and shrubs increase in importance in low rainfall regions and in regions in which livestock inventories contain high proportions of browsers, such as goats and camels (Le

Hourou, 1980).

The most economical method for improving deteriorated grazing lands is through natural means, that is, methods that do not require the planting of desirable species. This may be accomplished by control of unwanted plants, concentrating moisture or harvesting precipitation, or by grazing management. Grazing use of desirable plants is discussed in more detail in chapter 6. If natural revegetation is not feasible, the planting of desirable vegetation may be needed.

The machinery used as examples in this chapter can be expensive, difficult to obtain, and costly to operate and maintain. However, these examples may provide an opportunity to develop inexpensive and innovative techniques and simple equipment that employ the concepts upon which the more expensive equipment is based. Whether natural methods of revegetation or artificial planting are used depends upon the residual vegetation. In any case, the use of inexpensive and innovative techniques must be maximized.

Natural revegetation

For natural revegetation to be effective, there must be a residue of desirable plants to take over and occupy the site. More importantly, reduction of unwanted plants will not result in a stand of desirable plants if they do not already exist at the site. Undesirable vegetation that would severely compete with the establishment of desirable vegetation may have to be reduced or eliminated. Natural revegetation can occur quite rapidly following control of unwanted plants.

Plant control in range management involves reduction of unwanted or undesirable plants that have invaded or increased in a plant community. The migration of certain species out of their normal habitat is a major problem on rangelands in arid and semiarid regions. Each species or plant association has a habitat range to which it is naturally restricted. The environmental factors in a given habitat favor certain plant species and plant associations. This has the effect of confining the favored species and associations to the habitat type and rejecting others, but is true only in an undisturbed situation.

Plant species or plant associations are released from their habitat range restrictions by reducing the adjoining better adapted species or plant associations. This reduction or elimination of competition can be brought about by "continued disturbance.” The more common types of disturbance are frequent burning, drought, and continual and excessive harvesting. The greatest and fastest change can be caused by two or more factors acting in conjunction. Drought in conjunction with excessive harvesting, for example, has been a leading cause of disturbance in many areas of the world.

Control of unwanted plants will make more water available for the reproduction and production of desirable vegetation. This may be accomplished by chemical, biological, or mechanical means; by judicious use of fire; or by the use of certain animal species.

Control by Planned Fire

The use of fire is best known in relation to "slash-and-burn" agriculture in many tropical countries. This approach, if misused, is generally not beneficial in terms of stabilizing the long-term nutrient base. However, for subsistence agriculturalists, it is the easiest and cheapest way to clear land of unwanted vegetation, drive out game or predators and snakes, and provide the first crop with a flush of nutrients from the ash.

Rangeland burning may be designed to fit one or more objectives:

· Increase or improve livestock for age by eliminating some competing plants.
· Reduce litter and stimulate growth of desirable forage plants.
· Improve wildlife habitat by opening up dense plant cover while retaining diversity and adequate escape cover or nesting sites.
· Reduce high volumes of fuel, which lowers the chance of catastrophic wildfire in forests and scrublands.
· Improve visibility of livestock and wildlife after planned burning of certain ranges, especially in dense tree and shrub areas.

· Reduce the labor costs of handling livestock.
· Reduce predation losses in general.

Follow-up management after a prescribed burn differs in several ways from an emergency treatment that is usually applied following wildfires. The frequency of repeated burning is critical and, in general, frequent burning is undesirable as a management tool. Because prescribed fires are planned with specific goals under constraints that will assure minimum damage to plant cover and soils, much less injury to the site occurs. With proper planning for range improvements (including seeding where needed) and a grazing strategy to accommodate the prescribed burn, there should be little disruption of livestock operations. After wildfires, management objectives often are limited to minimizing expected damage from flooding and erosion, and the repair or replacement of range improvements (Jordan, 1981).

Management of burned areas can be directed to take advantage of the woody plant control caused by fire. Because wildfire is likely to cause greater damage to desirable plants and sites, such benefits are costly (Arizona Interagency Range Committee, 1977).

Effects on Soil

Depending on its intensity, fire may have far-reaching effects on soil characteristics, erosion, water yield, and plant succession. Removal of the litter cover, often exposing mineral soil, subjects the surface to the impact of rain; sealing the surface soil increases overland flow and attendant soil loss. In grassland or mixed grass-shrub areas, however, there is seldom enough litter to fuel catastrophic fires; light rapid burns, characteristic of grassland, seldom modify surface soil structure or seriously inhibit infiltration as do intense burns in forest, woodland, or chaparral. At the same time, fire seriously inhibits growth of woody plants.

Burning may significantly affect nutrients in range soils. Burning sometimes provides a temporary increase in the supply of nitrogen, phosphorus, and sulfur available for plant growth. Because nitrogen is frequently a limiting factor, especially on brush-supporting soils, the addition of even small amounts of available nitrogen may have a profound effect on revegetation.

Certain physical properties of soils may be adversely affected by burning. Particularly on forest ranges where slash and litter make heavier fuels, or in a thick scrub, intense fires may decrease soil aggregates and porosity and increase bulk density. These results usually reach a peak in the first or second postfire years, then disappear within about 4 years. A temporary increase in overland flow and erosion may be expected where the intensity of burn causes major changes in soil structure.

Some moderately permeable soils may develop resistance to wetting as a result of burning. This characteristic frequently has been observed as a result of fires in scrub, woodland, or forests where much fuel has accumulated. Apparently, a hydrophobic material moves downward in the soil and condenses on soil particles, greatly retarding percolation.

Infiltration also may be reduced if this water-resistant layer is at or near the soil surface. In any case, the "nonwettable" character may last a year or more, and may be a prime factor in the typically high runoff and erosion rates observed following fires on steep slopes.

Pattern in Vegetation

Most ranges subjected to random or intermittent burning are not uniform, and the vegetation comprises a variety of species, age, and density classes. Burn intensity varies greatly from spot to spot, and "skips" may occur where fuels were lighter, or where perverse winds altered the fire path. The resulting habitat diversity may be highly beneficial to wildlife, livestock, and landscape aesthetics. These benefits may be reduced or may be absent, however, following catastrophic wildfires.

Fire-Tolerant Species

Certain species are wholly dependent on fire, and tend to disappear from the plant community in the absence of burning, because their seeds require heat scarification to germinate. Forbs, seldom found on unburned ranges, may become abundant for a few postfire years, then decline abruptly. Other species may adapt to occasional burning by vigorous production of crown or root sprouts. Some shrub species may regain dominance quickly after intensive fires. However, young seedlings or sprouts are more susceptible to burning damage, and frequent fires could keep them in check (figure 7-2) (Reynolds and Bohning, 1956; Humphrey, 1962; Goumandakoye, 1984).

Large bunchgrasses can be damaged more than smaller bunchgrasses because more fuel is present, the fire lasts longer, and heat penetrates deeper into plant tissue of the larger plants. The presence of soil moisture retards heat buildup in the base of grass plants. However, the most effective control of a shrub might not be attained unless the soil is dry. Grasses tend to be more fire resistant than shrubs because of protected growing buds near the surface, and dormant grasses are more resistant than those having active growth.

Fire can be very effective in controlling nonsprouting shrubs such as sagebrush, but is only partially effective in controlling sprouting species, such as creosote-bush (Larrea tridentata) (Jordan, 1981).

Burning may affect the palatability and availability of forage for both livestock and wildlife. Cattle tend to congregate on recent burns, largely because of the accessibility of the tender, succulent new growth and the temporary communities of forbs that commonly develop in the early postfire periods. The use of weeping lovegrass, for example, may increase more than 50 percent after a winter burn (Klett et al., 1971).

Fires in productive grasslands may occur rather frequently; in less productive areas, burning may be possible only under unusual circumstances. Because grass crowns regenerate quickly after burning, light fuels soon accumulate and many areas can be reburned in as little as 1-3 years. On shrub-dominated ranges, however, this is not so. Usually, fuel accumulates more slowly, and, once burned, such areas may be relatively "fireproof" for 15-20 years. For example, ponderosa pine (Pinus ponderosa) ranges may be reburned on a 6- to l0year schedule.

Topography

As the steepness of the slopes increases, the rate of fire spread increases. The upslope rate is favored because of convection (the rising of hot air currents) and the more intense radiation that occurs on the upslope side of the fire. Winds tend to move upslope during the day and downslope during the night. Vegetation in depressions is more readily burned because the depressions are subject to wind tunnel effects.

Fuel

Sufficient fuel must be present to carry a ground fire, and under ideal conditions this should be at least 700 kg per ha. The surface-to-volume ratio affects the rate of combustion. A high surface area of small-sized fuel releases heat quickly; that is, the area has a high heat intensity. Larger fuels burn with less intensity but for a longer time. Intensity and duration are the controlling influences on plants and animals. Fire duration is related directly to total heat yield and fuel quantity, and indirectly to intensity. heat penetration into soil, bark, and other plant tissue increases as fire duration increases. Penetration is by conduction - the slowest rate of he at transfer. In addition to size and amount of fuel, environmental temperatures and moisture levels need to be prescribed within rather narrow limits (Jordan, 1981).

Weather

Weather patterns before, during, and after a burn must be considered in developing the prescribed control burn management plan. Of the three elements necessary for combustion - oxygen, fuel, and heat - fuel and heat can be manipulated by prescribing the weather conditions to be met during the burn. Before combustion can occur, the fuel must be raised to the appropriate temperature. All moisture must be removed before this temperature is reached, or else temperatures remain near the boiling point of water. Thus, fuel moisture, relative humidity, and temperatures are critical elements of weather that must be within narrow limits preceding and during a prescribed burn. While the cooling effect of water or moisture on a fire is elementary knowledge, its overall effect on a large fire is much more difficult to predict.

Air Pollution

Air quality near large urban centers is apt to be marginal at best, and any land management activity that tends to add significantly to the pollution is undesirable. Prescribed burning of extensive areas can be planned when fire weather forecasters predict airflow away from urban centers to avoid stagnation and/or mixing with polluted air layers. Most range burning involves relatively light fuels, and unless areas are very large, the air pollution - mostly from particulates - tends to be rather transitory.

Particulate matter from man-made fires can be a principal source of condensation nuclei necessary for the production of clouds and precipitation. Forest and grassland fires also yield charcoal, ash, and other products having a great diversity in form, structure, porosity, and absorptive capacity. These products are very different from those produced by the internal-combustion engine and by burning oil, rubber, or plastics (Arizona Interagency Range Committee, 1977).

Water Quality

Rangeland burning has not seriously affected water quality. Water quality studies have shown that initial conversion of chaparral to a grass-shrub range, for example, may temporarily increase nitrates in runoff to high levels, but these peaks do not last long and apparently are confined to the first or second year. Nitrate concentration then drops to a relatively low level (from 10 to 16 parts per million), and occasional reburning of the light fuels has little or no effect on nitrates. No significant increases have been noted in phosphorus, calcium, or total dissolved salts (Arizona

Interagency Range Committee, 1977).

Erosion

Wildfires often result in massive sheet and gully erosion, but prescribed range burning is much less of a problem because it is planned in advance. For example, steep, heavily wooded slopes that produce heavy sediment loads when burned, usually are not included in range burning plans. On such slopes, wildfires tend to be more severe, and leave little residue to provide soil protection.

Even the most carefully planned and executed range burn may produce sediment. Sediment yield declines rapidly, however, and even after wildfires, yield drops to near pre-burn levels within 3-5 years (Pase and Lindenmuth, 1971). Establishing a good grass cover early and subsequent conservative management virtually assure soil stability and low sediment yields on moderate slopes.

Effects on Wildlife

Well-planned prescribed burns may benefit wildlife. By maintaining a variety of vegetation, including brush islands of various sizes and ages, a highly diverse habitat can be provided. Habitat diversity encourages species diversity. Leaving shrubby areas of adequate size as escape cover and providing a number of serial stages of post-burn vegetation generally benefit both game and nongame wildlife (Bock et al., 1976).

Aesthetics

People with a limited understanding of the role of fire in the development of natural communities see a newly burned forest or range area as land management at its worst. They find the bare, blackened soil with occasional burned stubs of shrubs profoundly disturbing (figures 7-3a and 7-3b). However, like a plowed field or a homesite under construction, the disturbance does not last long. From a positive point of view, many serial plant communities, including some of the most colorful, exist only during the brief postfire recovery period; without fire, these communities would disappear forever (Arizona Interagency Range Committee, 1977).

Planning for Burning

The steps taken to develop a prescribed burn are planning, preparation, burning, and post-burn management. Technically qualified help must be available. Participation and cooperation of technical help with all interested persons adds to adequate planning. Planning provides for adequate preparation, which in turn promotes a successful burn. Burning should not be done unless planning indicates it is the most practical method in comparison with other management objectives or brush treatment methods. The area must have the potential to be improved. The costs of burning, such as labor, equipment use, supplies, and short-term loss of forage, should be considered. The size and shape of the area should be such that burning can be completed within the allotted time. In the United States, areas up to 400 hectares approach maximum cost effectiveness and manageability for daily burns.

Preparation includes the construction of firebreaks, fuel-break systems, and the placement of fire lines. For better control, fire lines are commonly started on ridgetops. Fires should not be started in valley bottoms but rather 10-100 m upslope. Various topographic features such as streams, roads, and old burns may be used as boundaries to control burns. Up-to-the minute spot weather forecasts are needed to determine wind velocity, relative humidity, and temperature. Wind speeds of 5-15 km per hour are desirable, but burning during higher velocity winds should be avoided. Finally, public information is important. It is better to have an informed public than to try to justify the burn to a concerned public after the fact.

The actual burning can be conducted by several ignition designs. The general principle is to have cool fires on the perimeter and hot fires in the center. Most designs start the fire 15-30 m inside the fire line. The sequence of ignition varies according to fuel, topography, and weather conditions. It should be remembered, however, that one fire tends to draw another fire to it through convection and radiation processes. There is no substitute for experienced help in conducting a prescribed burn.

Post-burn management objectives must be part of the prescribed burn project. Fire alone seldom attains the management objective. Herbicide treatments might be necessary to control regrowth of undesirable species. Where feasible, selective grazing by deer or goats can suppress sprouting. Seeding may be necessary to obtain the desired cover and erosion control. Grazing control also will be necessary to obtain adequate protection of the range until stand establishment (Jordan, 1981).

Benefits

The benefits of a range- burning program remain for varying lengths of time. The following can be considered directly or indirectly beneficial.

Increased Forage Production Increase in forage production is probably the main reason for range burning, usually to suppress undesirable woody plants. Burning may be insurance against some future decrease in carrying capacity due to woody plant encroachment, or planned as conversion from a brush to a grass-shrub range for increased forage production. Benefits may last 5-10 years, seldom longer.

Improved Forage Quality Forage quality may be improved because of the higher nutrient content and digestibility of the regrowth, or because of improved species composition.

Better Utilization and Livestock Distribution Utilization and livestock distribution may be improved. Reduction or retardation of woody plant growth permits better distribution of stock and more uniform forage utilization. Another benefit is the reduced manpower needed to work livestock, especially in areas that were formerly dominated by a dense shrub cover.

Increased Water Yield Significant improvement in water yield has been reported from treatment of some chaparral ranges by reducing transpiration losses. Most range burning, however, improves on-site water (soil moisture) savings and use (McKell et al., 1969).

Improved Wildlife Habitat Wildlife can benefit from the increased diversity of habitats following well-planned range burns. Wildlife food may be increased. Non-game birds and mammals also may benefit from the increase in habitat diversity caused by careful range burning.

Harvesting Precipitation

Natural revegetation is improved when more water is made available to desired vegetation. Poor infiltration of water into the soil is a key physical process. Often the soil surface can be treated to improve infiltration and prevent erosion, while the desired vegetation is increased or maintained.

Practices that help concentrate moisture and increase percolation in the soil include pitting, ripping, and contour furrowing (table 7-1).

These practices, as discussed here, are used on rangeland not in need of direct seeding. In fact, these operations should not be considered as a means of seedbed preparation. Basins or pits created through the use of cut-away pitters, road maintainers, or other equipment are used to concentrate moisture in a smaller area.

Ripping is used to break up impervious layers in the soil (figure 74). This usually increases percolation of water into the soil and reduces surface runoff.

Contour furrowing has the same effect as pitting. It is generally a more drastic treatment in that it involves more soil disturbance. As the name implies, water retention furrows must be on the contour.

Water spreading is used to conserve water needed for restoring or increasing the production of a forage crop. In water spreading, excessive peak storm flows are channelled out of an intermittent stream bed and spread out on gentle sloping land with a soil (medium or heavy textured soils) capable of absorbing and making productive use of the extra water (figure 7-5). A National Academy of Sciences publication, More Water for Arid Lands (1974), describes techniques of precipitation harvesting in some detail .

Direct seeding

Direct planting can speed range rehabilitation, but it is not a cure for all range ills. It is expensive; it is not universally applicable; and there is a calculated risk as to whether success can be achieved. On the other hand, if the following general considerations are carefully observed, and the options realistically evaluated, then chances of success can be high.

Method of Treatment	Type of Equipment	Swath Width	Working Weight	Kilowatt Requirements	Advantages
Pitting	1. Rotary Pitter (Spike Tooth)	1.5 m per unit. Generally pulls two units	6,200 kg/unit when filled with water	2 units 30-34 kw	1. Relatively che to operate

					2. Breakage free under normal operation
	2. Scranton Cutaway Disk Pitter	6 m per unit	750 kg/unit	1 unit 22-30 kw	1. All parts are standard, can be purchased locally 2. Seeding can be done in conjuncti with pitting 3 Hydraulic con enables uniform control of depth of pits 4. Opposite disc eliminates side draft
Ripping	1. Self-	3 m	450 kg/unit	35-45 kw	1. Units can be moved in pickup

	Cleaning Ripper	(2 units)			2. Self-cleaning of limbs and tras
	2. Road Ripper	N.A.	Pull type 2,700 kg; tool bar type 450 kg	90-110 kw	1. Will operate i rocky areas with very little maintenance
	3. Jay Hawker	2 m	4,500 kg +		1. Discernbile surface rip 2. 25 cm tube at 72 cm that fractu 1 m each way

TABLE 7-1 Summary of Equipment Used for Soil Surface preparation, advantages, and limitations

Method of Treatment	Type of Equipment	Swath Width	Working Weight	Kilowatt Requirements	Advantages
Furrowing	1. Model B Disc Type Contour Furrower Pull	2.4 m	2,700	35-45 kw	1. Seeding attach-ment allows furrow and seeding in one operation

Pull				
2. Holt Furrower	N.A.	Double disc 635 kg	25-36 kw	1. Continuous trenches or scalpin at 1 m intervals
		Single disc 400 kg	18-25 kw	2. Reversible disc always throws dirt downhill in trenchi
3. Front End Mold-Board Plow	N.A.	90 kg per unit attached to dozer point	50-70	1. Trench is made in front of uphill track; helps level tractor on slopes 2. Low cost of mol board equipment 3. Minimum time required to install trenching equipme
4. Mold-Board Plows	N.A.	Varies, about 225 kg per bottom	10-15 kw per bottom	1. Operating costs are low 2. Easily moved fr area to area
5. Road Maintai...	N.A.		Self-pro-pelled...	

Maintainers			pelled	
6. Hula *Dozer*	N.A.	N.A.	Fits any	1. Hydraulic contr tilt dozer is an excellent tool for digging contour trenches, ditches f pipeline, etc.

SOURCE: New Mexico Inter-Agency Range Committee, 1971.

TABLE 7-1 Summary of Equipment Used for Soil Surface preparation, advantages, and limitations - continue

Choice of Areas

In deciding whether an area should be seeded, the range manager should ask the following questions:

1. Is seeding absolutely needed?
Ranges can be rehabilitated more positively and at lower cost by

better livestock distribution, better systems of grazing, or reduced stocking. Only where the desirable native perennial forage plants are almost completely killed out is seeding essential. Such areas will have a forage condition rating of poor or very poor. Where the forage condition rating of a range is fair or better, and acceptable forage species are present, a range will generally improve under good grazing management.

2. Are proven methods available for the site?
If the answer is no, projects should not be undertaken until satisfactory procedures have been developed. Sites with the highest potential should be chosen; otherwise adverse site conditions may increase the risk of failure.

3. Can proven methods be used?
On many sites, the procedures are known for the general type of processes but cannot be followed because excessive rocks, steep slopes, or other factors prevent the use of appropriate equipment or the application of established methods.

4. Can the area be given proper grazing management after seeding? Seeding should not be started until proper grazing management can be assured.

Preliminary Considerations

Plant Cover The usual goal of developing a useful stand of desirable plants may be achieved by selective plant control or a change in grazing management. Seeding is an expensive and risky undertaking, and should be avoided if possible. As a general rule, at least one shrub and 10 desirable herbaceous plants per 9 m^2 should be present following revegetation.

Terrain and Soil Deep, fertile soils on level to gently sloping land are preferred sites for seeding. Shallow or rocky soils seldom have the potential to justify expensive reclamation measures. In some areas, excessive amounts of soluble salts in the soil require additional attention to ensure adequate plant establishment.

Precipitation In addition to being appropriate for the terrain and soils of the area to be seeded, the species selected should be well adapted to the precipitation regime of the area. Existing vegetation is generally a good indicator of available moisture. In areas of unreliable precipitation, the germination, establishment, and survival of the seeded species is better assured if available precipitation is augmented by additional water made available through precipitation harvesting techniques.

Competition Most plants used for revegetation are perennials. Seedlings of these species are often slow-growing and compete poorly at the seedling stage with existing, unwanted plants. A good seedbed will provide the best possible moisture conditions for germination and plant growth (figure 7-6). This requires the control of most existing plants before seeding.

Improvement of tropical and subtropical rangelands

Plant Materials The plant species selected for seeding must be compatible with management objectives (for example, palatability and growth period). It is important to use only those species and varieties well adapted to the soil, climate, and topography of the specific site being revegetated. If native species are chosen, seed of local origin should be used. Improved ecotypes, varieties, and introduced species may be available for revegetation and should be used. Species chosen for seeding must not only be adapted to the site but also appropriate for the future use and management capabilities of the site. (See chapter 8 for more details on plant selection.)

Plant Diversity A diverse ground cover will generally result in reduced soil erosion, and mixtures of grasses, forbs, and shrubs will better meet the multiple needs of the land user. The danger in monocultural seeding is that disease or insect infestation can eliminate the one species planted, whereas in a mixture, the differing characteristics of the various species would better assure a higher percentage of survival. The numerous ecological niches of variable terrain generally support higher levels of species diversity.

Seed Treatment The dormancy of most seeds can be overcome through the use of pretreatments designed to soften, puncture, wear away, or split the seed coat in order to render it permeable without damaging the embryo and endosperm within. They include physical and biological methods, dry heating, and soaking in water or chemical solutions. For further information, see Willan (1985). Various microbial treatments, such as nitrogen-fixing bacteria or mycorrhizal fungi, may enhance seedling survival.

Seeding Rates It is important to use enough seed to establish adequate plant densities, but not more seed than necessary to accomplish this. Too much seed can produce a stand of seedlings so thick that individual plants compete with each other. Species of plants, the number of pure live seeds (PLS) per kilogram, and the potential productivity of the site are major factors in determining the rate of seeding. PLS is determined by multiplying the germination of a lot of seed by its purity. Seeding rates providing 125-250 PLS per m^2 should be used when the seed is placed in the soil with a drill. Broadcast seeding is an inefficient method of revegetation, and should be used only where other methods cannot be used. Many broadcast seeds are left on the soil surface where germination and seedling establishment are tenuous. On steep slopes or sites inaccessible to drills or other equipment, broadcast seeding may be used. In this case, a doubled seed rate of 500 PLS per m² is recommended.

Planting Depth Proper depth of seeding naturally depends upon the species being planted. Optimal depth of seeding is roughly 4-7 times the diameter of the seed. Seeding equipment should be used that provides positive seed placement at the desired depth. More stands are lost because seeds are planted too deep rather than too shallow.

Timing The most desirable time to seed nonirrigated areas is immediately before the season of the most reliable rainfall, and when temperature is favorable for plant establishment.

Seed Distribution Uniform seed distribution is essential. Skips and missed strips should be avoided. Seeding equipment must be checked frequently to assure it is working properly and is not plugged.

Microenvironment In many areas, soil moisture is insufficient for germination and seedling establishment. Germination and establishment are also affected by high soil temperatures. Greater moisture availability and soil temperature regulation can generally be accomplished through practices such as mulching, summer fallow, and the use of various water-harvesting devices (Herbel, 1972a). In some instances, additional soil treatments might be necessary (Herbel, 1972b). For example, where heavy crusts have formed over medium- to heavy-textured soils in arid and semiarid areas the arid-land seeder (figure 7-7), or similar implements, can be used to improve soilmoisture relationships (Abernathy and Herbel, 1973; McKenzie and Herbel, 1982).

Seedbed Preparation The major objectives for preparing seedbeds are: (1) to remove or substantially reduce competing vegetation,

(2) to prepare a favorable microenvironment for seedling establishment, (3) to firm the soil below seed placement and cover the seed with loose soil, and if possible, (4) to leave mulch on the soil surface to reduce erosion and to improve the microenvironment.

Fertilization Where water is not a limiting factor, the addition of a nitrogen-phosphorus plant fertilizer in bands near the seed zone may be helpful in plant establishment. Broadcasting fertilizer is not advisable, because it will overstimulate competing plants.

Management All seedlings must be protected from grazing animals through the second growing season, or until the seeded species are well established. Under certain conditions, spraying to control weeds competing with the new seedlings can prevent the loss of a seedling. Rodents, rabbits, insects, and other pests should also be controlled where they pose a threat to new seedlings.

If not properly managed, seeded rangelands may soon be less productive than they were before removal of the original vegetation.

Animals can be herded by people on foot or on horseback to protect new seedlings from grazing damage, thereby avoiding the more expensive technique of fencing.

Direct Seeding Techniques

Direct planting may be accomplished by using a rangeland drill, press seeder, grain drill, range interseeder, browse seeder, or rotary spreader, as well as by aerial broadcasting, airstream, hand broadcasting, or other methods that take into consideration range seeding principles (Valentine, 1971).

Drill Seeding

Drilling is by far the most effective method of planting seed where site conditions permit. The seed is covered to the proper depth by the drill control; distribution is uniform; the rate of seeding is positively controlled; and compaction can be applied if needed. Several types of drills are available (Larson, 1980).

Rangeland Drill This drill is a rugged seeder with high clearance designed to work on rough sites (see figure 7-7). It has performed well on rough seedbeds. It can be converted into a deep furrow implement by removing the depth bands. The depth of the furrow is controlled by adding or removing disk arm weights. Weights up to 30 kg can be used. The seed-metering device on this drill can be adapted to handle a variety of seeds at widely varying rates.

Press Drill The press drill is designed for seeding on light, loose soils. A heavy press-wheel packs the soil. The seed is placed in the packed furrow and an adjustable drag covers it (figure 7-8). This drill cannot be used on rocky or rough seedbeds. The feed on the drill will not accommodate trashy seed unless it is especially designed for this purpose.

Ordinary Grain Drills The drills in this group are designed and built for use on cultivated fields. They are too lightly constructed for rough rangeland seeding. Breakage is a problem, and often the seed is not placed properly in the ground. For these reasons, they have limited use for critical area seedings.

Trashy Seed Drill This drill is equipped with two types of seed boxes, one for planting trashy seed, such as buffelgrass (Cenchrus ciliaris), and another for planting fine seeds, such as lovegrass or teff (Eragrostis spp.). The boxes can be used together or separately. The drill has a welded frame construction and uses rubber-tired wheels.

Broadcast Seeding

Broadcasting is any method that scatters the seed directly on the soil without soil coverage. However spread, the seed must be covered in some way if it is to germinate and become established. This can variously be done by dragging a chain or branches over the seeded area, raking with a hand implement, or driving a vehicle or livestock over the area after scattering seed. Seed size and the condition of the seedbed are important influences on the extent to which seed is covered with soil. A seedbed that is 5-8 cm of loose soil generally sloughs sufficiently to cover the seed. Covering the seed with a mulch is better than no coverage at all, but mulch coverage is inferior to soil coverage. If mulches are used in conjunction with seeding, best results are obtained by broadcasting the seed, covering it with soil, and then applying mulch.

Limitations to broadcast seeding are:

· Large quantities of seed are required (approximately double the amount used in drill seeding).
· Distribution of seed is often poor.
· Covering of seed is poor compared with drilling.
· Seed loss to birds and rodents can be great.
· Establishment is generally slower.

Aerial Applications Fixed-wing aircraft and helicopters are sometimes used where ground machines cannot operate efficiently. Aerial spreaders permit rapid treatment of large areas at relatively low cost.

Aerial spreaders are either rotary spreaders or venturi-type, ramair spreaders. The higher airspeeds of fixed-wing aircraft permit the use of venturi-type spreaders. Rotary broadcasters are suited to slower airspeeds or lower application rates. In fixed-wing aircraft, the hopper is located inside the fuselage, with a sliding gate that is operated from the cockpit. The application rate is controlled by opening or closing the sliding gate. In helicopters, rotary spreaders are either attached to the sides of the aircraft, or are suspended beneath it. Agitators within the hoppers ensure a continuous flow of materials. The equipment is calibrated for the desired application rate. Overlapping swath patterns are flown over the treatment area to give fairly even coverage. Spotters or markers are deployed to mark previously treated areas and area boundaries. The pilot should fly as low as possible to minimize drift.

Although aircraft can rapidly seed extensive areas, and quickly and effectively treat areas with slopes, soil conditions, or terrain that limit ground equipment, they do have noteworthy limitations. Airplanes require airstrips for takeoff and landing. Aerial broadcasting at high speed does not allow precise placement of broadcast materials. The broadcast material may also be moved by wind or water after application. Seed may be damaged during the operation, or destroyed by animals afterward. Also, much of the seed may be wasted because it is not placed on a micro-site that allows germination. (Larson, 1980)

Ground Applications Ground broadcasters are primarily of three types, each of which is discussed below.

Rotary Spreaders In this type of broadcaster, the seed falls from a hopper into a ribbed spinner that distributes the seed by centrifugal force. The width of throw depends on the size and weight of the seed, the speed of spinner, and wind velocity. Rotary spreaders may be carried by hand, mounted on a tractor or seedbed preparation unit, or trailed behind. They are generally powered by hand, by gasoline or electrical motor, or by power-takeoff attachments. Limitations of this type of seeder are:

· Swath width and rate of seeding vary with speed of travel and the speed of the spinner. In most of these machines, there is no mechanism to control the speed of the drive motor.
· Seed is not spread as evenly as from a drill box. The amount of seed is greatest near the center of the swath.
· Where seed mixtures are used in spreaders without agitators, seed is segregated by weight and applications are uneven.

Seeder Boxes of the Drill-Like or Fertilizer - Spreader Type In these broadcasters, a fluted or force gear-feed mechanism lets seed fall out of the bottom of the box onto the ground. The seed box is mounted on equipment such as brushland plows or brush cutters. In general, the seeder-box type of broadcaster distributes seed more uniformly than does the rotary type.

Dribblers A recent adaptation of this type of broadcaster is the "seed dribbler." The dribbler was designed to be mounted on the right and left side of the deck of a crawler tractor. It has a direct drive from a rubber-tired wheel riding on the tracks of the tractor and utilizes either fluted-force-feed or spoke-and-thimble metering mechanisms. The seed is metered onto the track pad just as it breaks over the front idler. It drops off the pad in front of the track and is embedded in the soil as the tracks pass over. The seed box units of the browse seeder (figure 7-9) can be adapted for use as dribblers.

Units With Airstream Seed Dispersal The seed is metered from a hopper either by gravity or forced gear into an airstream. Blower spreaders are available that broadcast both fluffy and slick seed, or fluffy seed only. The airstream can be created either by exhaust from equipment motors or by a fan designed for this purpose. Seed distribution is poor when wind velocities are high, and uncovered broadcast seed is subject to movement by wind and water.

Manual Equipment This method is as old as civilization. Many small areas are still seeded by a sower throwing seed from a sack suspended at a person's side with a shoulder strap. An experienced person can maintain a good distribution of seed by this method.

An adaptation of manual seeding is the Whirlwind seeder. This hand implement consists of a canvas seed container with a controlled feed that drops seed on a spinner. A crank is turned by the sower as he walks. The crank gear turns the spinner. The spinning action scatters the seed. Many hundreds of hectares are still seeded in this manner each year.

Land Imprinter

Rangeland revegetation often requires removing brush, preparing the soil, and sowing the seed in separate operations. If all three could be done in some simple mechanized operation, then large-scale rangeland renovation would be possible. The land imprinter is an innovative mechanism that attempts this.

The land imprinter is a simple cylinder 1 m in diameter and 2 m in length, and is pulled by an ordinary farm tractor (figure 7-10). The surface of the cylinder has V-shaped ridges that, under appropriate soil conditions, leave imprints of up to 10 cm deep in a furrow providing an indentation pattern that retains rainwater where it falls. These imprints provide a small water and litter catchment capable of storing sparse rainfall.

The imprinter is a hollow metal cylinder that can be filled with up to 2 tons of water to increase the imprinting pressure when used on more resistant soils. A variety of imprinting patterns are available offering flexibility for working with different soils, terrains, and climatic conditions. Seeding is done by an inexpensive broadcast type seeder mounted on the tractor or on the towing tongue of the imprinter, which allows the imprinter being towed to press the seed into close contact with the soil. The basic imprinting pattern creates a "runoff" groove that channels water to the seedbed groove where germination and plant growth can occur even under less-than-normal rainfall.

The machine rolls over and crushes the brush including individual plants with a basal diameter of up to 10 cm, although it is most effective on stems of less than 5 cm. The destruction of dense old brush is not as effective as with more specialized machines designed specifically for total brush removal; however, some brush is effectively killed, and the remainder is sufficiently damaged to delay regrowth until after the critical period of successful establishment of the new grass seedlings. At that time, the recuperating brush encounters strong soil moisture and nutrient competition from the new grass.

The land imprinter creates an additional benefit of mulching the existing vegetation into the soil to help retain moisture, provide soil aeration, and contribute to soil structures and nutrients. When the land imprinter is operated on very dry soil, crushing stems into the soil is less effective than on moist soil.

Transplanting

Plants grown in containers or nursery beds can be transplanted to the field. Planting material includes plants propagated from seed, stem layerings, root suckers, root cuttings, and shoot cuttings. The young plants should be about 75-100 days old when they are transplanted: they should not exceed 20-25 cm in height nor have a diameter of over 5 mm at the neck. In arid zones, the resistance of nursery plants should be conditioned by low and infrequent irrigation at least a month before they are planted out. The above-ground part of the plant should be cut back to 20 cm (hardwoods and grasses, but not conifers) and, where appropriate, roots should also be trimmed.

Planting Container-Grown Plants

The use of transplants, with roots growing into the planting medium, ensures the greatest degree of success and the least interruption of growth after planting. It is especially suitable for planting very young and tender plants. The techniques employed involve plastic bags, tubes, plastic container halves, and cartons.

When the work is properly done, few plants fail to grow. It is a labor-intensive approach that is useful where it can be justified. Producing plants in containers is a logical operation because some species have proven difficult to grow as bareroot seedlings. For example, some species have brittle stems and fragile root systems that are sensitive to breakage during bareroot lifting operations, and the extensive root system of others makes it difficult to culture them in seedbeds. Some plants just seem to grow better in containers (Landis and Simonich, 1984).

Production Facilities

Whereas many ornamental crops can be produced in a single greenhouse or screened structure, some plants may require as many as four separate facilities. An ideal container nursery consists of (1) a production greenhouse in which to grow the seedlings, (2) a cold frame or shadehouse in which to harden the plants, (3) a shadehouse in which to store the seedlings until they are distributed, and, where feasible, (4) refrigerated storage to maintain dormant stock for late-season planting. The advantages and disadvantages of different facilities are discussed in detail in Tinus and McDonald (1979).

Propagation Methods

The choice of propagation method is probably one of the most critical phases in plant production. The majority of seedlings in forest nurseries are produced by direct seeding, but the stringent stratification requirements and limited availability of many plant seeds may require other approaches.

Direct Sowing Direct sowing of seeds into the growth container is the standard technique for most conifer species and wildflowers. This propagation method is limited to those species with little or no dormancy requirement. If a stratification period or other pretreatment is required, the seed should be treated prior to the planned sowing date. Otherwise, the seed is soaked in water at room temperature for 24-48 hours and surface-dried before sowing.

The seeding procedure begins with the calculation of the proper sowing density based upon germination tests and past experience. Generally, several seeds are sown per container and are later thinned to one seedling per cell. The success of the direct seeding method depends upon the accuracy of the seed information. Germination tests vary from laboratory to laboratory, and no standardized tests are available for many shrubs and fortes. Since laboratory germination tests are run under controlled conditions, test results may differ from greenhouse germination. Sometimes the seed is obtained just before the sowing date and so there is not enough time for seed testing.

Germinant Technique The "germinant technique" is the sowing of pregerminated seed into the growth container. This propagation method is best for plants with simple dormancy requirements and species with seeds too large to handle mechanically. It is particularly suitable for seed lots of variable or unknown quality, because only good seed is sown in the growth container. Cell occupancy is maximized with this method as there are few blank cells and no subsequent thinning is needed.

The germinant procedure requires clean seed, so seed lots should be sterilized with chlorine bleach to reduce molding during stratification. The seeds are usually hydrated with a 24- to 48-hour soak and then prepared for the stratification chamber.

Seed can be germinated in "naked" stratification, where bare seeds are kept in a plastic bag or mixed with a moisture-holding material such as peat moss. The acidity of the peat moss helps retard seed molds during the lengthy stratification period, which can last up to eight months. Seeds are ready to transfer to the growth container when a white radicle becomes visible, but before the radicle becomes so long that it is easily damaged.

The planting operations consist of pouring the stratified seed out in a tray and picking out the germinants by hand or with tweezers. The germinants are placed in a depression or small hole in the potting soil in the growth container and covered with grit or perlite.

Seeds should be placed with the radicle oriented downward; if the radicle is pointed upward it will reverse itself in response to gravity, which may result in a stem crook in the young seedling.

Transplants Transplants are a third propagation method. Transplants are seedlings grown to the cotyledon state in trays and then transplanted into growth containers. This propagation method is best for woody plants with complex dormancy requirements, or for species whose small seeds would be almost impossible to plant by hand. This technique is ideal for seed lots of variable or unknown quality.

The transplant trays are filled to a depth of about 5 cm with standard potting mix and broadcastseeded by hand. The seed should be covered with a light application of a fine-textured material, such as sand-blasting grit.

When all the seedlings have been removed from the transplant trays, the soil is mixed, the trays irrigated, and the plants allowed to sprout again. Depending on the germination rate, the trays may produce up to three successive crops of transplant material.

Cuttings Rooted vegetative cuttings are started in trays and transplanted to growth containers. This is the best method for plants that are difficult to grow from seed or for which seed is difficult to obtain.

Cuttings are normally collected from plants in the field. The best season for collection depends on the species. Cuttings of two species of saltbush (Atriplex cuneata and A. confertifolia) rooted best when collected in spring or summer, but the rooting percentage dropped markedly when cuttings were taken in the fall (Richardson et al., 1979). Cuttings of some species, such as big sagebrush, root better when collected during winter dormancy (Alvarez-Cordero and McKell, 1979). A good step-by-step procedure for collecting cuttings is described by Norris (1983).

Before the cuttings are planted, they are often treated with a special hormone to stimulate production of root primordia. These "rooting" chemicals can be made from scratch by mixing indolebutyric acid (IBA) with common talc, or commercial products promoting root growth can be used. The best concentration of rooting hormone depends on many variables but, in general, the more difficult the plant is to root, the higher the concentration of rooting chemical that should be used (Norris, 1983). The rooting success of big sagebrush cuttings increased with increases in IBA concentration from 0.0 to 1.0 percent (Alvarez-Cordero and McKell, 1979). Treated cuttings should be inserted to a depth from 2.5 to 5 cm into a well-drained medium in a shallow rooting tray. Generally, the rooting medium does not contain any type of fertilizer, because of a possible stimulating effect on disease organisms.

Typically, the cuttings "callus over" first, and then produce adventitious roots from the callus tissue. Cutting success can exceed 95 percent with some species. The rooted cuttings should be transplanted immediately into a hole in the growth container; new roots should be protected from injury.

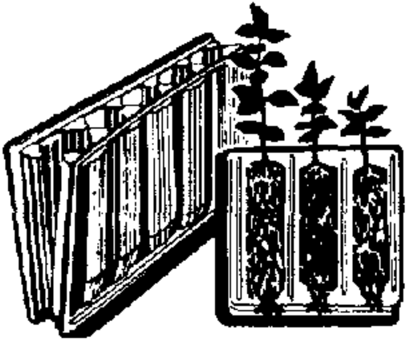


FIGURE 7-11 Tubepak container for mass propagation of plants for transplanting in harsh sites. Ribbed wall. of container direct the growth of roots downward and produce a root plug 0.2 m long (McKell, 1986).

Growth Container and Potting Media

Barker and McKell (1979) grew fourwing saltbush and grease-wood (Sarcobatus vermiculatus) in four sizes and types of containers ranging from 98 to 1,147 cm^3 and found that shoot length, shoot biomass, and root biomass all increased with size of container. A large variety of containers is available ranging from small unite in plastic or styrofoam trays to nursery pots: an ideal container is Tubepak (figure 711).

The best container size for good field performance is not necessarily the best container for seedling growth in the greenhouse. Plants grown in large containers generally perform beat in the field but require too much greenhouse apace and are costly to handle and ship. The best container also varies with plant species and environmental and soil conditions on the outplanting site.

The potting mix should be near pH 5.5 and have an electrical conductivity reading of less than 2.0 millimhos. Although there is much variation in potting mixes, mixtures of plain sand with sieved cow manure at a ratio of 1:1 are generally satisfactory (Weber, 1986). However, in some instances, special mixes may be desirable. For example, Ferguson and Monsen (1974) found that mixes containing peat moss and vermiculite produced better mountain-mahogany (Cercocarpus ledifolius) seedlings than did those containing sand. Ferguson (1980) studied 39 different potting media and found that no one mix was consistently superior. He did report that a potting mix of 50 percent peat moss, 30 percent arcillite aggregate, and 20 percent vermiculite is recommended for Bonneville saltbush (Atriplex bonnevillensis) and might be appropriate for other plant species native to alkaline soils. Mixing native soil into standard potting mixes can increase growth of some chenopod species. A survey of nurseries growing desert shrubs reported a wide variety of potting mixes that contained such diverse components as sand, cinder, peat moss, composted bark, charcoal, sawdust, vermiculite, perlite, and native soil. In lighter mixtures, it might be desirable to include some clay in the mixture, so that the root ball holds together during transplanting (Weber, 1986). Old termite mounds are often good sources of clay.

The Hardening Phase

The hardening phase is one of the most overlooked, yet most critical, periods in the growing cycle. It is relatively easy to produce an acceptable plant in the greenhouse, but these plants have a low rate of establishment unless they are properly conditioned so that they can survive and grow on the planting site. The two most important factors to consider in designing a hardening program are the planting date and the climate of the outplanting site. Many plant species grow very rapidly under the optimal conditions in the greenhouse, but this rapid growth consists of relatively large cells with thin cell walls and little tolerance to cold temperatures or moisture stress. Hardening is the process in which growth is reduced, stored carbohydrates accumulate, and the plant becomes better able to withstand adverse conditions (Penrose and Hansen, 1981).

The hardening phase has three major objectives:

1. To minimize physical damage during handling, shipping, and planting;

2. To condition the plant to tolerate cold temperatures during refrigerated storage or after outplanting; and
3. To acclimatize plants to the outside environment and satisfy internal dormancy requirements of some species.

Dormancy is another term that is often used in conjunction with hardiness. Dormant seedlings have been shown to have the ability to produce abundant new roots when planted in a favorable environment. This high root growth capacity should increase the ability of seedlings to survive and grow on harsh sites. Both dormancy and cold hardiness can be induced by proper scheduling of the hardening regime.

Hardiness should be induced in stages, and the process usually takes at least 6-8 weeks. The hardening begins in the greenhouse by shutting off the supplemental lights and by leaching excess nutrients out of the potting media. Night temperatures are lowered, and the seedlings are fertilized with a low nitrogen, high phosphorus and potassium fertilizer. Drought stressing should be carefully monitored because overly dry potting soil may be difficult to rewet, and stressed plants may not cold-harden normally. In the final hardening stages, temperatures are gradually lowered to the ambient level; tolerant plant species may even be taken slightly below 0°C.

Hardening can be achieved in either a cold frame or a shadehouse. Shadehouses are generally used to harden crops that are taken out of the greenhouse in summer or early fall when freezing temperatures are not expected.

Planting Bare-Rooted Plants

Under ordinary circumstances, bare-rooted plants are used in transplanting. Although such plants suffer greater loss and experience a greater interruption in growth than do plants grown in containers, the lower cost resulting from easier handling and transportation may compensate for losses and interruption of growth under most site and species conditions.

When planting stock has been properly wrapped, packed, and stored at the nursery, some plant death may still be caused by operational and natural hazards. Operational hazards include hauling plants from the nursery to the field, storage at the planting project area, and handling and planting practices in the field. Natural hazards that must be considered are weather, animal damage, vegetative competition, and insects and disease. Although natural hazards are often beyond control, the operational hazards can be largely minimized by careful planning, organization, training, and supervision. Each of these hazards may be crucial in determining whether the planting is a success; each must be carefully considered (Levin et al., 1953).

Hauling plants from the nursery to the field would seem of little danger; yet speed in getting them to the planting site is essential to achieving a high rate of survival. Wherever possible, stock should be picked up at the nursery at frequent intervals to eliminate storing plants for long periods in heeling-in beds in the field (Levin et al., 1953). When packaged stock is hauled in an open truck, the shipment should be covered with a canvas to protect against sun and wind.

Desiccation by the wind stream can easily ruin the exposed plants for planting purposes.

Storage of plants at the project planting area need not be a problem. Ordinarily, baled plants may be stored a week or 10 days in the original package if placed in a cool, moist, sheltered spot away from the sun or wind. Sheds or root cellars allowing more control of temperature and ventilation will make possible the extension of the holding period by two or three weeks if periodic inspections are provided to ensure that the packing material (moss or shingle tow) is moistened when needed.

If seedlings must be held at the planting site longer than a few days, they should ordinarily be "heeled in." This process should be attended to with the utmost care. The best heeling-in ground is moist (but well drained), easily worked soil exposed to neither direct sunlight nor excessive cold. If natural shelter is lacking, brush, burlap, or canvas shelter should be provided, but care must be exercised to keep this covering off the plants to permit adequate air circulation.

The seedlings are placed against the side of a shallow trench, their tops projecting above the ground slightly less than in the seed bed. They should be in a layer not more than 8-10 cm thick, and the side of the trench may be nearly vertical or slope as much as 45° (a slope simplifies the packing of a 10-15 cm layer of moist soil against the roots). A thicker layer of earth should be used if only one layer of seedlings is to be heeled in. The beds should be kept moderately moist. Good drainage is mandatory, however, because extremely wet seedlings will be hard to take out of the trench and standing water will kill the plants. Over-winter or dry-season heeling-in should always be avoided because of the damage to stock and resulting poor survival.

Poor handling of plants in the field is probably the greatest source of losses. A good rule is to do everything feasible to reduce the evaporation and transpiration of moisture from the plants. Care must also be taken to avoid smothering or drowning seedlings. Wherever possible, the stock should be left in the original bale for transporting to the planting area by truck or packboard.

The packing material in each package should be used by the planter to cover the roots of plants in his planting bag or tray to keep them moist. Each plant should be kept in this container at all times, not carried in the hand. The best container is a bag made of waterproof canvas or other stout waterproof cloth, with two loop handles. The bag should be divided into two compartments. A small bunch of plants from which the planter draws a plant for each setting is in one compartment, while in the other is the reserve supply. Each compartment should have enough wet moss or shingle tow to cover all roots.

Improper planting practices are the greatest hazard to planting survival. Some critical items are noted below (Levin et al., 1953, Penrose and Hansen, 1981):

· Do not plant in ground that has been "burned red" by a hot fire.
· Do not plant in bark or rotten wood, unless it has decomposed and is mixed with dirt.
· Place the plant at the correct depth (about 6 mm deeper - never higher - than in the nursery); it is easy to see the old ground line on the plant.
· Spread the main roots to a near natural pattern, not doubled or sharply bent.
· Tamp the soil firmly around the roots at the bottom of the hole, as well as at the top, to eliminate air pockets, and anchor the plants so that they cannot be easily pulled up.
. Leave the plant in an upright position with the root collar even with the general ground level, not sunk in a hole or raised on a mound.

Weather is a major factor in seedling survival. The season of planting should, of course, be appropriate to the area to be planted.

Ideal planting weather is warm enough so the planters are comfortable without heavy clothing and humidity is high, due to mist, fog, or rain, so that the roots will not dry out under ordinary care. During severe seasons, many plants may succumb to heat and drought. Careful planning, however, can cut losses even during the worst years.

Where local climate will allow it, planting should be done so that at least two months of moist soil conditions remain before the dry season. The choice of the planting season is naturally during the period when the stock is dormant. In temperate zones, most planting is usually done in the autumn or spring; in the tropics and subtropics it is usually done early in the rainy season. The usual practice is to initiate planting after a certain quantity of rain has fallen, or when the soil is wet to a certain depth. In Zambia, for example, planting is undertaken when the soil is moist to a depth of about 30 cm (Laurie, 1974).

Damage to plantations by mammals and birds may usually be traceable to a particular genus (Levin et al., 1953). Three main groups of animals are of concern: the rodents (including the true rodents and the lagomorphs, or rabbits and hares), the ruminants (or cudchewing animals), and birds.

Competing vegetation is harmful except where needed to prevent severe erosion, and plantings should be made before a competitive sod forms or the sod should be scalped where the plant is inserted. Scalping or removal of sod, brush, or other competing vegetation is necessary on some sites to prevent stunting or killing of plants. This occurs principally in three ways:

1. Root competition. This is most serious on dry sites, but it may also be a factor on the wetter highquality sites in dense vegetation. Greatest damage occurs during the critical first year or two when sod and brush roots are feeding in the same root zone as the transplant.
2. Competition for light. This is most serious on the better sites, where the surrounding vegetation and brush shades or suppresses

the plant.
3. Smothering. This is most serious on sites that produce tall grasses and weeds that die in the fall and mat down over the plants.

Scalping of the area around the spot to receive a transplant is done by the planters at the time of planting, using a planting mattock or grub hoe. The depth and diameter of the scalped area will vary according to the density of the vegetative root systems and foliage.

Selected practices

Throughout the rangelands of the world, there are large areas where desirable forage plants have been reduced in vigor or eliminated by past abuse. Such lands produce few benefits and are a detriment to adjacent lands. Even with controlled grazing by livestock and, in some cases, complete protection, depleted areas might require 20 or more years to develop desirable plants. Secondary succession is very slow, or nonexistent in arid and semiarid rangelands where the vegetation has been depleted. Revegetation is the only means by which to establish desirable plants for protection and production in a relatively short period of time. Some examples follow.

Syria Transplanted container-grown seedlings of old man saltbush survived very well in western Syria (Csa) when placed in furrows dug 3 m apart. (For explanation of climatic classifications, see figure 1-1.) Plantings were made in moist soil at the beginning of the rainy season. Subsequent protection of planted areas resulted in the appearance of rangeland species such as bulbous barley (Hordeum bulbosum) and Artemisia herba-alba.

Israel Seeding trials in Israel (Csa) indicated that Mediterranean saltbush (Atriplex halimus) could not emerge from a compacted surface (Koller et al., 1958). Seeds were sown in moist, shallow furrows at a depth of 2-5 cm. The covering soil was firmly packed in part of the furrows while it was left loose in others. Upon drying, the packed soil formed a hard crust that most of the germinating seedlings could not penetrate. Full rows of seedlings appeared within 3-4 weeks after sowing in the furrows covered with loose soil.

Iran Seeding of many shrubs was generally unsuccessful in the dry steppes (BSh) and desert (BWh) of Iran because of unreliable germination (Nemati, 1978). However, transplants of fourwing saltbush, quailbush (Atriplex lentiformis), and Mediterranean saltbush had good establishment on arid to semiarid rangeland.

India Post-sowing compaction with iron packer wheels (20 cm x 5 cm, size; 9.2 kg, weight) reduced the soil water required for the germination and emergence of annual fortes in a loamy-sand soil (Yadav and Gupta, 1977). In order to obtain 75 percent ultimate emergence without compaction, a soil moisture level of 9 percent was required in the seedbed, whereas the use of the packer wheel resulted in the same emergence with 6-7 percent soil water.

Paroda and Mann (1979) studied the effects of seeding on a number of dryland sites in western Rajasthan, India (BWh). They reported that planting the seed 1 cm deep on the ridge of furrows 75 cm apart was the most advantageous. They used Lasiurus sindicus, buffelgrass, birdwoodgrass (C. setigerus), diaz bluestem (Dichanthium annulatum), and blue panicgrass (Panicum antidotale). Some of these species have yielded in excess of 3,000 kg per ha. Seedings of the local climax species indicate that average production can be increased to about 2,000 kg per ha. However, seed production and the availability of desirable species have been a problem.

Australia Successful regeneration of rangelands in the northeast pastoral zone of South Australia (BWh) depends on: (1) trapping windborne seed, (2) concentrating moisture from light rains, and (3) protecting young seedlings from the blast effect of windborne sand (Young, 1969). A tyned pitter was developed for use in this area and has resulted in natural revegetation of desirable plants such as bluebushes (Kochia spp.) and saltbushes (Atriplex spp.).

Shrubs were successfully established by tyne pitting and broadcast seeding on hardpan sites in New South Wales (BWh, BShw) (Stanley, 1978). A mixture of old man saltbush (A. nummularia), bladder saltbush (A. vesicaria), bluebush (K brevifolia), and black bluebush (K pyramidata) were used. Initial establishment was favored by above-average rainfall, but growth of old man saltbush was more tolerant of prolonged flooding than either bladder saltbush or black bluebush. However, growth of the latter two species was greater during a subsequent hot, dry period during which old man saltbush and black bluebush began to die. Bluebush responded to subsequent rainfall, but old man saltbush did not recover.

Water ponding assisted in reclaiming bare scalds in arid (less than 25 mm annual precipitation) portions of New South Wales in Australia (Newman, 1966). The treated areas were relatively flat and the soils were deep clays to clay loam. Banks were constructed to collect water in a pond to depths of 15-25 cm. Good stands of several saltbush species were obtained.

A plow with opposed disk blades and a centrally mounted ripper point was developed for furrow-seeding in northwestern Australia (BShw) (Fitzgerald, 1968; 1982). Early experience indicated that a bank, formed when loose soil was heaped onto compacted ground, collapsed when wetted. The bank of loose soil proved more stable when a ripper point was placed between the disks. Buflfelgrass, birdwoodgrass, and kapokbush (Aerva tomentosa) have been successfully seeded with this technique.

A contour seeder was designed and developed in western Australia for a variety of conditions. The basic machine consists of two opposed disks to till soil into furrows and mounds, and one central ripper to create a broken seedbed for plant rooting. Discontinuous cultivation is activated by a short lift on the linkage every 10-40 m depending upon slope. In salty soils, the two opposed disks are placed so that a mound with a niche in the center is created. The niche is about 50 mm above the salt pan. Salts leach to the high ridges on the mound leaving the niche relatively free of salts. A seed and vermiculite mix is dropped every 2 m in the niche.

Australia is also a leading country in the application of aerial seeding to pasture improvement. For example, in the dry savannahs of Queensland, native pastures have been oversown with Stylosanthes spp. through aerial seeding. Initially, S. humilis and superphosphates were distributed shortly before the rainy season over roughly plowed seed beds, from which all timber had been mechanically cleared, windrowed, and burned. In 1974, S. humilis was superseded by S. hamata (Verano), as the latter was resistant to anthracnose (Colletotrichum gloeosporioides), as well as being more productive and competitive. S. scabra (Seca) was mixed with the Verano seed at a ratio of 1 kg to 3.5 kg, as Seca is better adapted to areas of the pasture with heavier soils. The stylo seed was not treated, and hard seeds were broken down through natural weathering.

From 1973 onwards, efforts were made to reduce costs of establishment by eliminating capitalintensive clearing operations, and aerially sowing into open savannah with no prior treatment other than burning or heavy grazing just before sowing. Plowing was eliminated after clearing the savannahs in 19751976, and the stylo seed and superphosphate rates were reduced from 1977 onwards. All of the methods have resulted in stylo-dominant pastures, but the times required to reach dominance have varied: 1 year on cleared and cultivated areas; 2 years on uncleared areas at high rates of seed and superphosphate; and 3 years when only 1 kg per hectare of seed and 60 kg per hectare of superphosphate were spread.

Heavy grazing (more than one animal unit per 2 hectare) immediately after sowing is essential for obtaining good establishment of stylo. Cattle selectively graze native grasses in preference to stylo during the first 2-3 months of the growing season, and this greatly increases the competitive ability of the stylo seedlings when compared with lightly grazed or ungrazed situations. Stylo dominance in the pasture increases with increased stocking rates. In Australia, improved pastures carry about 10 times more cattle than native pastures. (Edye and Gillard, 1984)

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Criteria for plant selection

Project planning

When planning any revegetation project or program, the first two questions that should come to mind are: what is the purpose of the project or program, and what are the management tools to be applied? Clear answers to these two questions would eliminate many problems and would restrict plant selection to a relatively limited number of possibilities. In the past, a number of philosophical views have been argued endlessly: for example, the selection of native species versus exotics; herbaceous species versus woody species; the planting of nursery-grown seedlings versus direct sowing; and single species versus mixed plantations (Le Hourou, 1984). Many personal biases would be avoided by first answering the two questions posed above.

Once the scope and objectives of the project or program are clearly defined, many controversial issues would solve themselves if a number of other questions were asked:

· What is needed?
· What is available?
· What technologies have proven successful under similar circumstances, if any?
· What are the principal constraints in establishment and in management?
· Is the project or program technically and economically feasible, and is it socially acceptable?

The purpose of a revegetation project may be single or multiple, simple or complex. Some examples are given below:

· To rehabilitate depleted rangelands and pastures;
· To establish multiple species for both agroforestry and

sylvopastoral uses;
· To establish fodder-shrub plantations as drought buffer reserves;
· To stabilize watersheds, which will achieve a combination of goals;
· To develop a program for the reclamation of salt- or alkaline affected land (in either rainfed or irrigated conditions to produce fodder, fuel, amenities, etc.);
· To provide windbreaks and shelterbelts for the protection of agricultural lands;
· To stabilize sand dunes, preventing encroachment upon productive lands;
· To establish fuelwood plantations;
· To increase the potential for timber production by planting highly productive species and ecotypes;
· To reclaim mined land, quarries, and mine-waste dumps;
· To establish protective plantations that will arrest erosion or sedimentation in order to reduce the maintenance costs of highways, bridges, airports, reservoirs, and settlements, without other envisaged direct benefits; and
· To establish amenity plantings - for example, in association with

settlements or highways.

Socioeconomic and management considerations in feasibility studies

Large-scale projects should be the subject of feasibility studies clarifying the cost-benefit ratios of the proposed undertaking. Such studies, however, should depart from conventional economic analysis to the extent that social values, informal-sector economics, "the cost of doing nothing," and other factors that might affect project relevance and success are taken into consideration. Unfortunately, this broader approach to project definition is seldom employed in part because some benefits are not easy to quantify - particularly in amenity projects, in watershedmanagement projects, or in erosion control and anti-desertification projects. Social returns (such as reduced air or water pollution, recreation, and improved quality of life), although real and significant, are similarly difficult to quantify in monetary terms, but should nevertheless be factored into the planning equation.

Feasibility studies should also include management assessments. In fact, a general and mandatory rule should apply to all proposed revegetation projects: no project should be undertaken unless provision has been made for subsequent long-term management, with appropriate legal sanction and financial requirements that are acceptable to the land users. The infringement of this rule has resulted in general failures in the past - yet it continues to be ignored, despite the common sense of properly managing rangelands after expensive revegetation. Particular attention should be paid to the cost of protection and maintenance of revegetated areas. Studies have shown, for examples, that the cost of fencing and guarding is an overriding factor in cost-benefit analysis (de Montgolfier-Kouevi and Le Hourou, 1980). Another major constraint to successful revegetation is the difficulty of finding an alternative source of income for the populations concerned from the time that the projects are initiated until the time that they are fully productive.

Adaptation to ecoclimatic conditions

In all cases, the planner must match site characteristics with plant ecological requirements. In many cases, the selection of revegetation sites is imposed by local conditions in response to a pressing need for protection. The only possibility then left to the project planner is to select plants that are able to meet the ecological requirements of the site while having a growth rate rapid enough to enable the project to fulfill its role in a reasonable period of time. Some ecologically well-adapted plant materials may have an intrinsic growth or expansion rate that is too slow to achieve any practical result in a reasonable period of time; the reproductive rate may be insufficient or unknown, or in many cases, seeds may not be available in sufficient quantity. Hence, the introduction of a faster growing species may be preferred. In the Mediterranean Basin and in Africa, Australian or American shrubs and trees are commonly used instead of native species.

Latitude, Day Length, Photoperiodism

Some species may have a wide area of distribution, such as:

Atriplex	20° Lat. N. to 45° Lat. N.
Atriplex halimus	25° Lat. N. to 55° Lat. N.
Eucalyptus camaldulensis	15° Lat. S. to 45° Lat. S.
Cenchrus ciliaris	35° Lat. N. to 35° Lat. S.
Cynodon dactylon	50° Lat. N. to 40° Lat. S.

Each degree in latitude results in a difference in day length of 12 minutes at the time of the solstice. Thus, the day-length requirements between the extreme northerly and southerly populations of Atriplex canescens or A. halimus may differ by as much as five hours, making southerly populations unfit for the northern part of the geographic area of distribution and vice versa. For this reason, most species of Atriplex do not produce flowers under intertropical latitudes, even though they can still thrive vegetatively under these conditions. Therefore, in photoperiodically sensitive species, care must be taken to address latitudinal compatibility between the zone or origin of the plant material and the site to be revegetated.

Rainfall and Rain-Use Efficiency

The amount, distribution, and variability of precipitation must be as similar as possible from the sites of origin to the revegetation site. For example, plant material from areas with a predominantly summer rainfall regime should not be expected to perform well in sites with a winter rainfall regime. Within a given rainfall regime, it is usually safer to take plants from dry areas to more humid sites, rather than from humid to dry sites. There are some exceptions, however: Acacia saligna, for example, thrives on sand dunes in southwestern Australia under a Mediterranean climatic regime with rainfall ranging from 700 to 1,200 mm per annum; yet, in the Mediterranean Basin, it grows successfully when annual rainfall is as low as 200-300 mm. Similar cases are known with some Eucalyptus species. Such situations, however, are the exception rather than the rule. Rain-use efficiency (kg of dry matter per ha per year per mm) may be a good general indicator for evaluating environmental suitability (Le Hourou, 1984).

Temperature

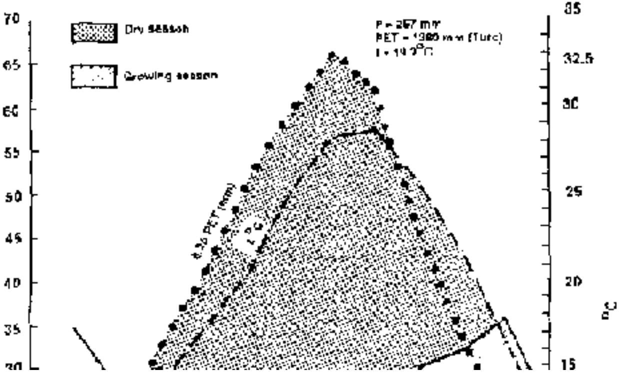
Tolerance of low or high temperature is usually a limiting factor to plant growth. The easiest criterion to use for assessing tolerance of temperature conditions in a first approximation of potential adaptability to a site is to compare mean minimum and absolute temperatures of the coldest month on the one hand and the mean maximum and absolute maximum temperature of the hottest month on the other. The monthly number of freezing days or the number of hours or days below or above given thresholds may be useful comparisons for some tangential or marginal cases. A certain margin of security must be included, particularly in cases of rough topography, since there may be rather large differences in temperatures over short distances. Temperature inversions may occur in any given elevation according to local topographical conditions; for example, valleys may be colder in winter and hotter in summer than the surrounding slopes above them.

Evaporation, Evapotranspiration, and Water Budget

The site water budget is perhaps the most important single ecoclimatic parameter to be considered in any revegetation project. Water budget must be considered in a space and time perspective with due consideration for topographic, hydrological, and edaphic (soil) factors.

The regional water budget can be schematically shown comparing mean monthly rainfall and mean monthly potential evapotranspiration. When potential evapotranspiration is not known and cannot be easily calculated, a good substitute is the ombrothermic diagram (Bagnouls and Gaussen, 1953), which shows mean monthly rainfall expressed in millimeters on a scale double that of mean monthly temperatures expressed in degrees Celsius (see figure 8-1). The dry season is defined by $P<2t$, where "P" is mean monthly rainfall in mm and "t" is mean monthly temperature in °C. It has been shown that the rainy/dry season threshold $P< 2t$ is very close to $P < 0.35$ PET, where PET is mean monthly evapotranspiration using Penman's or Turc's method of calculation (Le Hourou, and Popov, 1981).

The distribution of the P/PET ratio over the year shows the average length of dry and rainy seasons. In combination with mean monthly minimum temperature distribution, this allows for the evaluation of the length of growing season, the latter being defined by (1) a positive water balance (including water reserves in the soil), and (2) a mean monthly temperature above 10°C (50°F) or a mean monthly minimum temperature above 5°C (42°F).



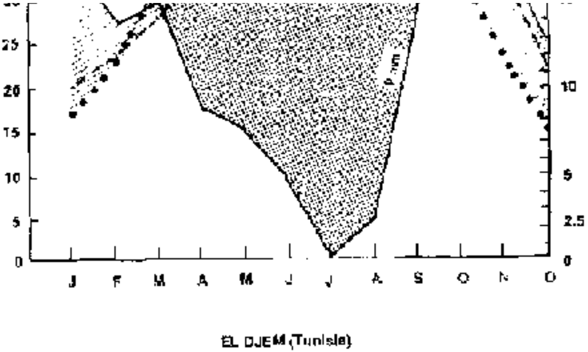


FIGURE 8-1 Typical ombrothermic diagram.

It may be useful or necessary at times to assess the probability of drought. In a first approximation, this may be evaluated from the coefficient of variation of monthly and annual rainfall. A good indicator of drought probability is the coefficient of variation (c.v.) of annual rainfall (standard deviation over mean). In the Mediterranean Basin, for instance, a c.v. of annual rainfall equal to

25-30 percent would indicate semiarid conditions with a drought probability of 20-25 percent; a c.v. of 50 percent, arid conditions with a drought probability of 40-60 percent; and a c.v. of 100 percent or above, desert conditions with drought probability of 80 percent or above (table 8-1, and Le Hourou, and Popov, 1981).

P (mm)	Africa North of the Sahara	West African Sahel	South Texas USA	Northeastern Brazil
	Coefficient of Variation of P (percentage)			
10-100	80-200+	50-00+		
100-200	60-100	40-50		
200-300	40-70	30-45		
300-400	35-55	25-35		
400-600	30-50	20-30	30-40	30-50
600-800	20-35	15-25	25-35	25-65
800-1000	20-25	15-20	20-30	30-50
1,000-1,500	15-20	12-20		

Mean annual precipitation = P
CVP = Standard deviation x 100/P

SOURCE: Le Houérou and Norwine, 1985

TABLE 8-1 Relationship Between Mean Annual Precipitation and

Variability/Probability of Annual Rains in Arid Zones

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P (mm)	**Africa North of the Sahara**	**West African Sahel**	**South Texas USA**	**Northeastern Brazil**
	Coefficient of Variation of P (percentage)			
10-100	80-200+	50-00+		
100-200	60-100	40-60		
200-300	40-70	30-46		
300-400	56-55	26-36		
400-	30-50	20-30	30-40	30-50

600-800	20-35	16-25	26-36	26-66
800-1000	20-26	16-20	20-30	30-60
1,000-1,500	16-20	12-20		

Mean annual precipitation = P
CVP = Standard deviation x 100/P
SOURCE: Le Hourou and Norwine, 1985

However, the local water budget at the site level may be different from the regional bioclimatic water budget because of physiographic and soil factors variously inducing infiltration or runoff. Runoff zones are obviously drier than the regional average and therefore more drought-prone, whereas zones with satisfactory infiltration may exhibit only temporary water deficits, or no deficit at all, because of the presence of a temporary or permanent groundwater table within reach of the surface vegetation.

The water budget at a site may also be assessed in a nonquantitative manner using the natural vegetation: for example, the presence of xerophytes, mesophytes, hygrophytes, phreatophytes, and other vegetation indicators.

Adaptation to soils

Soil suitability for plant production may be based upon a combination of water budget and nutrient status (including oxygen). These, in turn, depend upon physical and chemical characteristics. The main physical characteristics to consider are discussed below.
Texture

Texture, particularly of the topsoil, largely controls permeability and water intake, and therefore water budget. Texture also controls, to some degree, nutrient status. Some species are adapted to coarse textured soils (psammophytes), others are suited to fine-textured soils (pelophytes), and still others may be little affected by the texture factor. Textural differences play a large part in the ability of seeds to emerge or roots to penetrate dense soils composed of a majority of clay-sized particles that tend to form dense surface crusts when dry.

Structure

Structure affects soil permeability and drainage, redox potential (and therefore waterlogging), and temporary or permanent aerobic or anaerobic conditions (root asphyxia, H2S toxicity, etc.). Some species can tolerate anaerobic conditions, while others are very sensitive and fail to grow or survive.

Depth

Soil depth, in conjunction with permeability, controls water storage capacity, which is a key characteristic in arid and semiarid lands. Deep soils may store large amounts of water during short rainy periods where it is subsequently available to deep-rooted plants, thus buffering the effect of climatic aridity. In the arid zone, high productivity is achieved on deep sandy soils because virtually all rain is stored and then released to plants. Under higher and more regular rainfall, however, deep sandy soils tend to be relatively less productive because of lower nutrient status. Nutrients, as well as water, can be a limiting factor to plant growth.

Shallow, stony, impervious soils, on the other hand, hold little water and can cause water stress in plants. Shallowness and imperviousness may, however, be corrected with adequate treatment, such as ripping, in order to break an impervious caliche (indurated calcium or magnesium carbonate) hardpan. Pitting, chiseling, and sweeping may considerably increase water intake by breaking a superficial thin-clay-sealed or loam-sealed pan that may have rendered the soil almost impervious.

The sealing of an arid-zone soil surface is a very potent factor in desertification and is sometimes reinforced by lichens or by microscopic blue-green algal encrustations. This sealing can be overcome by breaking the soil surface and roughening it with mechanical tools or by the hoof action of grazing animals, a technique that may greatly increase productivity. Conversely, if heavy traffic by hooves or equipment occurs when the soil is wet, compaction may occur to exacerbate the existing low permeability.

Water Storage Capacity

The role of water storage capacity obviously increases with aridity and rainfall variability. All the ancient techniques of "runoff farming" over 3,000 years old in the Near East, are based on water storage capacity - collecting surface runoff and storing it in the soil profile of run-in areas (Evenari et al., 1971).

Storage capacity may be increased by using well-known techniques tending either to reduce runoff (pitting, contour furrowing, or contour benching) or to collect runoff water and use it on another nearby site employing water harvesting and spreading techniques.

These techniques, which may be 2,000-3,000 years old, make it possible to grow crops on arid-zone soils. Under the meskat or jessour system techniques in the arid zone of Tunisia and Libya, for example, over 10 million productive olive trees have been grown for centuries in areas receiving from 80 to 300 mm of precipitation (Le Hourou, 1959).

Chemical Characteristics

Among soil chemical properties, pH is one of the most important. Some plant species require acidic soil (acidophilic), others require alkaline conditions (basophilic), and a few are relatively indifferent to this factor. Nutrient status may also be a serious limiting factor. In many instances, however, nitrogen, phosphorus, or sulfur deficiencies can be overcome either by using fertilizers, ashes, or manure, or by using plant species that have low nutrient demands. The presence of toxic elements should also be taken into consideration. The most common toxic elements in soils are sodium, boron, and various chloride or sulfite and copper salts. The presence of toxicity calls for the use of specialized tolerant species, and often has important implications with regard to how the land and vegetation are utilized. Salt-tolerant species may be further differentiated as xerohalophytes, mesohalophytes, hygrohalophytes, and tropohalophytes (plants adapted to dry, mesic, wet, and alternately wet and dry soil conditions, respectively).

Revegetation projects are often concerned with the reclamation of soils that have been drastically disturbed or are inherently poor in their ability to support a vegetative cover. These soils call for specialized plant species adapted to particular habitats and able to grow well under various climatic conditions. Examples of these special areas, and the genera adapted to them are presented below:

Sand dunes: Calligonum, Haloxylon, Acacia, Phyllodineae, Hedysarum, Caragana, Tamarix, Eucalyptus, Cassia, Casuarina, Panicum, Pennisetum

Badlands (shales and marls eroded in gullies): Pinus, Cupressus, Ailanthus, Opuntia, Festuca, Agropyron, Hedysarum, Atriplex

Shallow soils: Pinus, Eucalyptus, Opuntia, Prosopis, Agropyron, Oryzopsis, Medicago, Bromus

Flooded/waterlogged soils: Taxodium, Pinus, Salix, Populus, Saccharum, Arundo, Phragmites

Mine waste: Eucalyptus, Tamarix, Atriplex, Maireana, Elymus, Agropyron

Saline/alkaline soils: Atriplex, Maireana, Tamarix, Lagunaria, Phoenix, Elaeagnus, Sporobolus, Puccinellia, Spartina, Distichlis.

Adaptation to physiography, geomorphology, topography, slope, and aspect

Physiographic characteristics of a site may play a very important role in positively or negatively modifying regional climatic data in terms of energy flow, temperature, evaporation, rainfall, and soil water budget (through runoff/infiltration and erosion/sedimentation, drainage, the presence or absence of waterlogging, or a satisfactory water table, and so forth). A simple calculation would show, for example, that a northern slope with a 30° dip under 40° latitude N. would have a potential evapotranspiration equal to only one-third of a similar southern slope, and therefore, if rainfall remains similar in both cases, the water budget would be three times greater in the former than in the latter (Le Hourou, 1972). The selection of species to be planted is therefore likely to be different in the two cases, if optimum use of the sites is sought.

Physiography may also strongly affect local precipitation if the site is exposed to rain-bearing winds; is in a rain shadow; or is subject to descending, warm, dry winds, similar to the Fhn of the southern Alps, the samun winds of Iran, the Santa Anas of California, the chinooks of the eastern Rockies, the berg winds of South Africa, the nor'westers of New Zealand, or the zonda of Argentina.

Geomorphology and slope may also play an important role in determining rates of erosion or sedimentation and soil depth, thus greatly affecting soil fertility and water budget. Hence, species selection and plant productivity calculations must be modified accordingly (see table 8-1 and figure 8-1).

Ability of introduced species to compete with native vegetation

Plant competition should be considered from the viewpoint of short-term establishment, long-term survival, and perpetuation of stands. Competition during the establishment stage may be reduced by the application of herbicides or mechanical treatments (mowing, plowing) to the native vegetation until the desired species become established. When high yields are desired, competition from weeds may be eliminated on a continuous basis by regular or periodic treatments.

Long-term perpetuation of stands of introduced species will depend on their ability to reproduce either vegetatively (for example, by suckers, runners, stolons, or rhizomes) or by seed. Some fast growing exotic species are not able to perpetuate themselves on the site and may need to be replanted after a number of years. However, some exotics have become invading pests (Opuntia spp., Prosopis spp., Nicotiana glauca, Parkinsonia spp., Euphorbia spp., Jatropha spp.).

Competition within mixtures, when mixtures are desired, can be reduced by using species with different root systems (for example, shallow-rooted species mixed with deep-rooted ones) as well as including species that have different seasonal patterns of growth.

Competition may also be reduced by selecting species according to their adaptability to microhabitats such as mounds, depressions, flat areas, or sloping areas. Diverse topography will create diversity in the resulting vegetation composition. Doing this, however, requires skill and experience and is not always practical for large-scale programs.

Use regimes

Forage Production

Revegetation for forage production is quite common either by range seeding (with or without water conservation techniques) or planting fodder shrubs and trees for fodder reserves. Sown pastures, also called "tame pastures," may be included in rangeland systems either for continuous grazing, for seasonal grazing, or for deferred standing hay to be used in periods of shortage. Range seedings are commonplace, and suitable species are well documented for use in a number of countries.

The use of rhizobial inoculants with annual or perennial legumes for agricultural areas is well known. The use of well-adapted trees that can serve both as forage and to enhance nitrogen in the soil is an obvious need. Various shrubs and trees are not only excellent sources of nitrogen but also serve larger roles in integrated land-use systems (National Research Council, 1979).

Fodder Trees and Shrubs

Fodder tree and shrub plantations probably occupy over one million hectares in the arid and semiarid zones. Some particularly useful trees and shrubs include acacias (such as Acacia saligna, A. Senegal, A. tortilis, A. albida, cacti (Opuntia ficus-indica), salt bushes (Atriplex nummularia, A. canescens, A. halimus), saksauls (Haloxylon persicum, H. aphyllum), and mesquites (such as Prosopis juliflora, P. glandulosa, P. chilensis, P. alba, P. cineraria). Some are managed as wooded grazing lands with evergreen oaks, such as Quercus rotundifolia, Q. ilex, Q. suber, and Q. lusitanica (for example, the circum-Mediterranean region and parts of California), with mesquites (India, Chile, Mexico), with olive trees (the Mediterranean Basin), and with acacias (East and West Africa).

Plantations of fodder shrubs or fodder trees may be integrated either into pastoral systems or into farming systems. They may be used as browse either for seasonal, deferred grazing or as buffer fodder reserves for periods of drought (Le Hourou, 1980). They may be directly browsed, or cut and carried to livestock. Fruits, such as the pods of Acacia or Prosopis, may be collected, stored and fed, or sold as concentrated feed. Some of these plantations may be intensively managed and fertilized for high productivity, such as Leucaena leucocephala, which can produce as much as 5,000-10,000 kg of dry matter per ha per year of high-protein feed. Opuntia ficusindica plantations in Mexico, Brazil, South Africa, and North Africa may produce 5,000 15,000 kg of dry matter per ha per year under arid and semiarid conditions. Atriplex nummularia plantations may produce 2,000 5,000 kg of protein-rich dry fodder per ha per year in the arid zones of North Africa, the Near East, and South Africa with or without complementary irrigation, while 10,000 kg of dry matter per ha per year under brackish water irrigation have been obtained in Israel (Pasternak et al., 1979; Le Hourou, 1986). Two-year-old Atriplex canescens plantations in southern California produced 9,189 kg per ha (Goodin and McKell, 1971). Plantations of tree lucerne (Cytisus proliferus) and tree medic (Medicago arborea) are also capable of high production of quality browse under relatively intense management systems.

Fuelwood Production

Fuelwood is in short supply in many countries, particularly around towns and cities. One solution to the fuelwood problem is to plant woodlots of fast-growing species of genera such as Eucalyptis, Pinus, Populus, Casuarina, Azadirachta, Cassia, Albizia, and Gmelina. Such woodlots may prove to be excellent investments when the site and species are appropriately chosen (National Research Council, 1980).

However, particular care should be taken in establishing woodlots of fast-growing trees, as such species are frequently heavy consumers of soil nutrients, and the soils of woodlots can become seriously depleted with the loss of the nutrients contained in the exported fuelwood. Further, in many species of fast-growing trees, the greater exposed juvenile growth increases their susceptiblity to predators, disease, and desiccation. Hence, solutions to fuelwood scarcity are increasingly being sought in diversified strategies, possibly including the establishment of woodlots, fuelwood production in agroforestry systems, improved natural forest management, and more efficient fuel utilization.

Windbreaks, Shelterbelts, and Living Hedges

Although windbreaks and shelterbelts cannot alter regional climatic conditions, they do change microclimatic conditions at the ground surface by reducing wind speed and advective energy inputs (the oasis effect). Shelter plants are thus able to reduce temperature and potential evapotranspiration, which in turn reduces the water demand of crops, natural vegetation, and animals. An added benefit is the production of fuelwood and timber.

Traditionally, cut branches from thorn trees and shrubs are used for fencing and corrals. In the tropics, these structures need to be renewed frequently because of the destruction of the cut wood by termites, thus resulting in substantial losses of native trees and shrubs. The establishment of permanent live hedges composed of local thorn shrubs could help solve this problem.

Maintenance and improvement of Soil Fertility

The role of trees and shrubs, particularly legumes (such as Acacia, Prosopis, Albizia, Gliricidia, and Leucaena), in maintaining or restoring soil fertility has been documented for a number of agroforestry systems: for example, with Acacia albida in the semiarid tropics of Africa, with Prosopis cineraria in the Rajasthan Desert of India, with Leucaena leucocephala in various countries of the humid tropics, and with desert shrubs throughout the drylands of the tropics and the subtropics.

Leaf litter, combined with the shading effect of the canopy, produces a recycling of nutrients (N. P. Ca, K, Mg) brought from deep, subsurface layers to the topsoil. As a result, yields of millet under Acacia albida, Prosopis cineraria, or other legumes are up to two-and-one-half times greater than in open fields in otherwise similar conditions (Charreau and Vidal, 1965; Garcia-Moya and McKell, 1970; Mann and Sazena, 1980).

Conservation and Rehabilitation

Anti-erosion revegetation projects have been successfully carried out in various countries under extremely arid conditions. For instance, saksauls (Haloxylon persicum, N. ammodendron, and Calligonum spp.) have been used in the Near East.

Sand dunes can be stabilized by planting short shrubs, such as Buphorbia spp., perpendicular to the direction of the wind. Commonly called palisades, this method requires a great deal of labor since the plants must be closely spaced - from 10 cm intervals at the base of the dunes to as close as 2 cm intervals near the tops of dunes. Lateral rows also need to be created so that the effects of lateral sand transport will be diminished. This may result in a grid or checkerboard pattern. However, there must be enough space between shrubs so that small quantities of sand can pass through. Otherwise, the formation of dunes superimposed over the old dunes could result. Local demonstration areas might be required to determine palisade orientation, spacing, and height.

Whatever the species chosen, a program of protection and managed use must be established and maintained to ensure the longevity of the effort. Regardless of the method used, the major obstacle is always the provision of appropriate management strategies and an alternative livelihood for the populations concerned until the revegetation projects become self-supporting. Ways and means to accomplish this should be spelled out in the feasibility studies.

Other Uses

Revegetation projects may consider adjacent plantations that can sustain multiple uses for one or more of the reasons previously mentioned, such as using cacti (Opuntia spp.) for its fruits, fleshy pads, and joints in northern Africa; mulberry (Mows alba) for fruits and wine making, feed for livestock and wildlife, and silkworm forage; cashews (Anacardium occidentale, European filberts (Corylus avellana) and pistachio-nuts (Pistacia vera) for fruits; Eucalyptus spp. and Prosopis spp. for honey. Other uses include chemicals, gums, and tannins from species such as carob (Ceratonia siliqua) and Acacia spp., and fibers from Agave spp.

Availability of seeds and plant materials

After considering the environmental conditions of the site(s) to be revegetated and the purpose(s) for which the revegetation program was designed, the choice of species is the next task. A range management specialist will wish to examine lists of grass, forte, tree, and shrub species in the local flora and become familiar with the field characteristics of the most desirable species. From such information sources, comparisons can be made with well-known species used in other parts of the world that have been successfully used in revegetation projects.

It may be difficult to obtain the desired and best-adapted species. If many of the species tentatively chosen for revegetation are native or "wild" species in the local flora, an established commercial source of seeds may not exist. Two options are available to those planning the project. The first is to compare the ecological similarity of the project site with other areas of the world where adequate seed sources do exist and obtain a mixture of high-performance seeds that meet project objectives. The species must have a broad genetic base and meet standards for purity and germination. The rangeland seed industry generally follows a practice of requiring seeds on a pure live seed (PLS) basis, which assures that seeds will be free of trash and weed seeds and have a live embryo capable of germinating according to specified percentages (Valentine, 1979).

The second alternative is to develop or assist in developing local sources of seeds ecologically adapted to site conditions and capable of productivity and stability under expected project conditions. The development of such sources may have long-term beneficial consequences for future projects. With appropriate incentives, local individuals or small companies may be trained to collect and process clean seeds from local fields and uncultivated areas. Some grass species may be grown under field conditions for increased volume production. Obviously, considerable advance planning is required to supply the volume of seeds needed for large projects.

The assistance of specialists in native seed production may be needed. Depending upon seed availability, seed mixtures developed for a revegetation project may include native species of the project site as well as seeds obtained from analogous locations elsewhere.

In the western United States, several seed companies have developed considerable expertise in collecting seeds from native stands or producing them under field conditions (Crofts and McKell, 1977).

Practical procedures for cleaning and handling assure high seed quality. Further information regarding the availability of germ plasm appropriate for range improvement projects in the tropics and subtropics could be obtained from the following sources:

Division of Tropical Crops and Pastures
Commonwealth Scientific and Industrial Research Organization
Private Mail Bag, MSO
Townsville, Queensland 4810

Australia

Forest Resources Development Branch
Forestry Department
Food and Agriculture Organization of the United Nations
Via delle Terme di Caracalla
00100 Rome
Italy

International Council for Research in Agroforestry
P.O. Box 30677
Nairobi
Kenya

Maintenance of biological diversity

Questions of reduced biological diversity have been raised in relation to range improvement projects carried out in the western United States during the 1940s and 1950s. Many of the early projects were designed for sites where the perennial bunch grasses were severely reduced by overgrazing, and where other shrubs of low palatability to livestock had come to dominate the sites. Remedial measures to remove or reduce the dominant shrubs, such as the application of broad-spectrum chemical herbicides or mechanical removal, also had an adverse impact on other species susceptible to the drastic control methods. The result was a severe reduction in the species diversity of the range vegetation.

In addition to the loss of diversity caused by the control measures, the number of species included in the seeding mix were very limited, sometimes consisting only of wheatgrasses. Experience in securing a satisfactory degree of establishment and in managing grazing on stands of varying species composition demonstrated that monospecific stands were easier to manage than stands with greater diversity (Valentine, 1979). Other factors, however, such as the susceptibility of a monoculture to insect infestations (Haws, 1978) and the need for species diversity to provide forage over various seasons or year-round, suggested that several species with diverse characteristics should be included in the seed mix. Plummer and colleagues (1968) recommend that the seeding mix consist of several plant types for restoring big-game range and areas of multiple use because of four advantages that can accrue to the project:

· A mixture is better suited to the varied terrain and climatic conditions of mountain rangelands.
· A variety provides several nutritional sources for game animals and livestock.
· Including several species with different seasons of maturity prolongs the period during which green feed is available to animals.
· Mixtures provide a better overall degree of ground cover than does a single species.

Since the late 1970s, state and federal government regulations in the United States have required that a diverse and effective mixture of species be used for the reclamation of lands drastically disturbed by surface mining for coal. If seed supplies are available, species native to the area are to be given priority over non-natives.

There is ample reason to argue that the emphasis should be placed on a high degree of adaptability and productive capacity in choosing species rather than their merely being native. Nevertheless, the critical factor is to provide the site to be revegetated with a sufficiently diverse spectrum of species that ecological stability will be assured during periods of environmental stress. Equally important is that various ecosystem functions that depend on a diverse vegetation will be supported.

An important issue is how range improvement operations that are planned in an often limited perspective can deal with the fundamental problem of maintaining biological diversity in rangeland ecosystems. Concern has been expressed in numerous conferences and symposia that the continued intensive development of agricultural and natural resource areas is seriously depleting the world of many valuable species upon which future genetic development and even the survival of mankind may depend (U.S. Department of State, 1982). Range improvement practices that require some degree of control over various competing species, so that they will not prevent the establishment of the seeded species, should be planned with a sensitivity for ways to maintain the overall diversity of the plant community. Further, range technicians who select species for seeding should include those that will have a high degree of adaptability and longevity on the site to be revegetated. Where possible, seeds of desirable species from the local area should be included in the seed mixture. Subsequent management practices should seek to avoid highly selective grazing that damages only certain species that are needed to maintain the diversity and the stability of the range ecosystem.

Plant improvement

Plant improvement consists for the most part of developing genotypes that are superior when compared with the average of the species or genetic entity. Although the selection of superior types is the most expeditious way to obtain improved plants, by crossing genotypes that have particularly valuable features, a new entity is created that combines the desired features of the original parents into one. Thus, the plant breeder is able to produce plants that are more specialized than those that previously existed. However, this degree of specialization can limit the range of adaptation of the improved genotype, unless its selection and performance testing are done in an environment similar to that of the sites where the improved plant is to be established.

Ideally, a species to be used in range seedings needs to possess vigor, as well as considerable variation, in order to fit into the diverse niches and environments of rangeland sites. Although it is desirable to have uniform and highly productive species, it is also important to have sufficient genetic diversity within a population that some individuals survive and prosper in various rangeland situations. In range plant improvement, it is possible to make selections from the diverse gene pool of existing grasses, fortes, trees, and shrubs in order to identify the superior types available. As newer techniques in biotechnology become available, they can also be applied to the challenge of unlocking the great reservoir of variability and useful features in arid and semiarid plant populations. The breeding of more specialized varieties, as has been done for pasture grasses and legumes, serves as an example of what can be done for tropical and subtropical rangelands.

An example of a successful plant improvement program is the extensive study, selection, and breeding of plants in the genus Agropyron by the U.S. Department of Agriculture's Agricultural Research Service group at Logan, Utah. Considerable progress has been achieved in the development of new varieties of wheatgrasses and crosses with closely related species (Dewey, 1983). Asay and Knowles (1985) documented the release of seven improved cultivars of Agropyron and Elymus for rangeland improvement. Because of their importance for forage and conservation use, many other taxonomic groups of grasses are the subject of efforts in genetic improvement. They would include Bouteloua (Heizer and Hassell, 1985), Panicum, Sorghastrum, and Tripsacum (Vogel et al., 1985), as well as Cenchrus, Eragrostis, Digitaria, Leptochloa, Muhlenbergia, Setaria, and Sporobolus (Voigt and Oake, 1985).

The improved palatability of range plants is often mentioned as a desirable plant improvement goal, but according to a review by Voigt (1975), the factors that influence palatability must first be understood. Plant chemical composition is a major palatability factor, but morphology, succulence, disease resistance, and stage of growth are also involved. The selection of superior plants with these characteristics is necessary to produce plants with improved palatability, and to relate palatability to management strategies.

One of the most critical needs is for grasses with a superior ability to germinate and establish themselves in stressful environments. Wright (1975) has reviewed the work of plant breeders in developing species with special traits useful in rangeland situations. He cited results in the improvement of Panicum antidotale for increased drought tolerance, Bouteloua eriopoda for improved seed set, B. curtipendula for greater seed dormancy to avoid excessively early germination, and P. obtusum for improved seed viability.

Heinrichs (1975) pointed out that in many rangeland areas, the scarcity of adapted legumes appears to be a problem for maintaining the nitrogen level in the soil adequate to support good plant growth. Most of the research work in the United States has been done on legume fortes such as Trifolium, Medicago, and Vicia. According to Rumbaugh and Townsend (1985), more than 25 improved cultivars of legume species adapted to humid and semiarid rangelands are now available, but the greatest challenge is for an improved legume cultivar adapted to range sites receiving less than 250 mm of precipitation annually. There is also a need to develop improved varieties of leguminous shrubs. The International Livestock Centre for Africa,

The International Center for Agricultural Research in the Dry Areas, the Central Arid Zone Research Institute (India), and the Commonwealth Scientific and Industrial Research Organization (Australia) are among the growing number of organizations engaged in research into fodder legumes in the tropics and substropics.

McKell (1975) emphasized that inclusion of adapted fortes and shrubs in range improvement projects was a means of increasing the productivity of harsh sites. By including selected ecotypes of droughtand salinity-tolerant shrub species, such as Atriplex, Ceratonia, Acacia, and Purshia, the stress-tolerant biotypes within the populations would be the ones to establish themselves and survive. Release of "Rincon," a new variety of Atriplex canescens, exemplifies the opportunity to improve range plants by making selections from a breeding population of superior individuals. However, to be successful, such improved varieties must be genetically flexible for long-term survival (Stutz and Carlson, 1985). Interest in improving shrubs for range revegetation was stimulated by an international shrub symposium (McKell et al., 1972) and by the Shrub Research Consortium, a group of universities and natural-resource agencies in the western United States. A symposium at the 1985 meeting of the Society for Range Management featured reports of some of the research groups. Monson and Davis (1985) pointed out that the family Rosaceae has a high potential for superior selections from species favored for their value as browse in range improvement programs and with certain genera, for symbiotic fixation of nitrogen. Other families of shrubs favored in improvement programs are the Compositae (McArthur et al., 1985), for their aggressive habit, persistence, and potential for industrial chemicals, and the Chenopodiaceae, for their protein content and tolerance to salinity (Stutz and Carlson, 1985).

Many leguminous trees and shrubs are important sources of feed for animals and for range improvement in East Africa (Pratt and Gwynne, 1977). Based upon nutritional and ecological observations, Bogdan and Pratt (1967) recommended species for reseeding in Kenya. During the 1940s and 1950s, Bogdan assembled a collection of tree and shrub legumes at the National Grassland Research Station in Kitale, Kenya, for the purpose of selecting those with superior growth, adaptation, and productivity, but much remains to be done with this valuable genetic resource. Further information regarding the role of trees and shrubs in African livestock production systems is contained in the proceedings of the International Symposium on Browse in Africa (le Hourou, 1980).

In summary, there is serious need for the development of improved plant materials for rangeland revegetation use. Within the diversity of plant species native to arid and semiarid rangelands, there is ample variability from which to select in developing varieties suitable for the stressful conditions characteristic of rangeland environments. Traditional methods, in concert with newer techniques in biotechnology, hold promise for developing improved plant materials needed to meet the challenges of renewing degraded rangelands.

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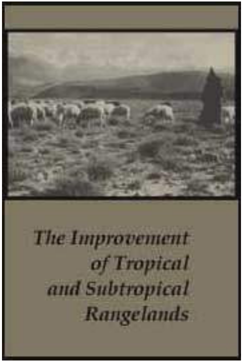
The Improvement
of Tropical
and Subtropical
Rangelands

The Improvement of Tropical and Subtropical Rangelands (BOSTID)

Part II

Introduction to the case studies

Successful efforts in rangeland improvement are dependent on a thorough understanding of environmental context and the broad range of interactive social, economic, and political factors that affect project formulation and implementation. The most useful and socially responsible way to achieve this understanding is through the analysis of indigenous social adaptations to particular regions. The case studies in this book illustrate the adaptations to various settings in Africa and Asia.

The adaptations described in several of these case studies (specifically, 1, 2, 5, and 6) were characterized over 20 years ago and their use here should not be taken to indicate that they continue to be reasonable reflections of current local conditions. The evolution of range and pastureland systems of resource management in response to stress has been discussed in a companion study, Proceedings of the Conference on Common Property Resource Management (National Academy Press, 1986).

The first case study, "Pastoral Regimes of Mauritania," contrasts the adaptations of the Rigaibat Lqacem of the Saharan zone with those of the Ahel bou-Lobat and other groups associated with the Mauritanian Sahel. Case study 2, "The Beni Mguild Arabs of Morocco," illustrates a complex system of adaptations to a mountainous region dominated by winter precipitation. The third case study, "The Kel Tamasheq of Mali," explores the material culture and diet of the Oulliminden tribe of the Malian Sahel. Not only do these case studies underscore the logic of indigenous adaptations, but provide insight into the probable social and environmental consequences of inappropriately designed rangeland improvement projects in the regions described.

With few exceptions, the livestock projects undertaken by governments and international assistance agencies in tropical and subtropical regions have focused on cattle. In the highly degraded rangelands of the drier zones, however, other forms of livestock often enjoy a comparative advantage. In recent years, renewed interest has been expressed in the camel. Case study 4, "Dromedary Pastoralism in Africa and Asia," discusses camel husbandry and its potential contributions to modern economies. Case study 5, "The Mountain Nomads of Iran: Basseri and Bakhtiari," describes two largely sheepbased pastoral systems seasonally adapted to the Zagros mountains and their associated lowlands. Case study 6, "The Marri Baluch of Pakistan," describes a complex livelihood system that incorporates herding, agriculture, gathering, and wage labor. Case study 7, "Changing Patterns of

Resource Use in the BedthiAghanashini Valleys of Karnataka State, India," describes the dynamic interactions among differing human communities, external forces, and the regional resource base in the Uttara Kannada district of the Western Ghats.

Many contemporary efforts in rangeland improvement and regional development are based in systematic environmental analysis and the complementarily of Western science and traditional knowledge. Case study 8, "Kenya: Seeking Remedies for Desert Encroachment," describes the approach taken in UNESCO's Integrated Project in Arid Lands in northern Kenya. Other contemporary efforts draw more heavily from the past. "The Hema System in the Arabian Peninsula," case study 9, describes the successful reintroduction of one of the world's oldest systems of rangeland management into the drylands of the Middle East.

Case study 10, "Wildlife Land Use at Athi River, Kenya," explores the possibility that the most ecologically sound and economically rewarding use of rangeland in many areas may be for wildlife ranching rather than for conventional livestock projects. Case study 11, "Camel Husbandry in Kenya: Increasing the Productivity of Ranchland," discusses the complementary integration of camel and cattle husbandry on four ranches in Kenya. Both papers reflect a trend toward greater innovation in land use. Case study 12, "The Potential of Faidherbia albida for Desertification Control and Increased Productivity in Chad," while focusing on the contributions of a single species, discusses ways of better integrating agriculture and animal husbandry in the African drylands. The final case study, "Improving Nigeria's Animal Feed Resources: Pastoralists and Scientists Cooperate in Fodder Bank Research," describes a modern approach to the creation of fodder reserves that is functionally similar to the ancient hema system described in the ninth case study.

Pastoral regimes of Mauritania

DOUGLAS JOHNSON

Mauritania remains one of the few countries in the world in which pastoral activities continue to play a prominent role for a large segment of the population, despite some instances of sedentarization (1) and other modifications of livelihood reflecting changing ecological, social, economic, and political conditions. Because Mauritania covers a wide latitudinal range and contains a variety of physiographic and climatic regions with generally arid characteristics, it offers a range of marginal environments whose utilization can only be accomplished by a pastoral nomadic life. Existing in precarious balance with these marginal environments are several pastoral regimes that, in their evolution, have arrived at a combination of pastoral and agricultural activities in an attempt to best use the available resources. That the various combinations of camel, goat, sheep, and cattle herding, together with date and grain cultivation, have continued to function effectively for centuries is a telling comment on their basic rationality and efficiency.

Physical geography

Mauritania can be divided into two markedly different physiographic and environmental zones. The southern Sahel, particularly along the coast, is of low relief, with the coastal plain extending inland for 500 km before encountering a line of cliffs. The coast is a barren one, (2) replete with coastal dunes and depressions, such as the Aftout as-Sahali, while sand dunes interspersed with barren regs, or stony surfaces, stretch deep into the interior. Once away from the littoral zone, it is possible to find some grazing areas despite the generally barren nature of both dunes and regs, but vegetation is severely limited by scanty and often saline water resources. In the interior of the country, occasional plateaus rise above the level of the surrounding plains, and some of these, most notably the Adrar, contain important oases. North and east of the Adrar are several northeast to southwest oriented bands of sand dunes (extensions of Erg Chech and Erg Iguidi) that give way still farther north to the reg deserts of Ghallamane and Yetti. (3) Occasional low massifs (al-Hank, Zemmour Labyad), often with steep cliffs, as well as the Hamada of Tindouf and Wadi Draa, add variety to an otherwise sterile and monotonous landscape.

The southern and central regions of Mauritania are influenced by a tropical climatic regime, the impact of which extends as far north as the Tropic of Cancer to the northwest of the Adrar. But east of the Adrar, the 50-mm isohyet that marks the northern boundary of the tropical influence dips below the parallel of 18°N. (4) Rainfall totals increase rapidly south of this line, and the 50-mm isohyet, marking the southern boundary of the Sahel, extends westward from just north of Dakar across northern Senegal and along the southern boundary of the Hawd. Although the exact onset of the rains is variable, most of it falls during the summer months. The rainy season usually begins in May around Slibabi and Nma, and in July around Nouakchott, Boutilimit, and Tidjikja. As the rains proceed northward, the variability in their occurrence from year to year increases steadily (as, for example, the recording of 247 mm at Atar in 1927 followed by only 31 mm in 1928)5 and their inception is sometimes delayed until as late as August in Tagant and the Hawd. These summer rains are part of the Inter Tropical Convergence Zone, and their arrival is signaled by the outburst of violent thunderstorms that also characterize the Kel Tamasheq country farther to the east. Along the entire coast rainfall is light, but the effects of the summer heat are somewhat modified by the influence of the cool offshore current as well as by the frequent occurrence of fog and dew. In the south, three major seasons can be recognized: a hot, humid summer from June until the end of August, during which most of the year's precipitation occurs, and a winter season that is subdivided into a cool, dry period and a hot, dry period. (6)

Vegetation flourishes during the rainy summer season, is adequate during the cool, dry season, and is thoroughly dried out during the hot, dry period, when water - or, more accurately, lack of water - is the crucial concern, and a decided concentration of all nomadic groups around permanent sources of water is the rule. In the south, the vegetation is composed of a savanna complex of various acacias (Acacia nilotica, A. senegal, A. flava, and A. tortilis) with an understory of grasses and herbs, particularly cramcram (Cenchrus biflorus). (7) To the north, in keeping with the declining rainfall totals, the occurrence of acacias becomes less frequent, and the understory diminishes to scattered clumps of had (Cornulaca monacantha) and sbat (Aristida pungens). In the far north, acacias are restricted to the beds of wadis (usually dry intermittent streams) or especially favored locations in the uplands where they form a major part of the diet of camels; had, sbat, awaraj (Calligonum comosum), and various halophytes form the preferred forage of camels and sheep.

North of the Adrar, the major climatic influence is derived from the Atlantic, rather than from the tropics, and the regime is distinctly Mediterranean in character. Unlike southern Mauritania, precipitation in the north occurs at the very end of the summer and during the early months of winter. (8) Although this rainfall may be locally heavy, totals throughout the northern areas are small, and the distribution is usually sporadic and highly localized. While permanent water supplies can almost always be located in wadi beds and beneath sand dunes at no great distance from the surface, most of the rocky expanses, hamadas and regs, are devoid of dependable water resources. Here the winter rains are of crucial importance, for they cause a rich ephemeral vegetation to spring up wherever they occur, while the rainpools that collect in isolated hollows assure adequate water for man and beast during the winter grazing season, thus permitting the exploitation of what would otherwise be barren and unusable areas.

Migration cycle

The Rigaibat Lqacem

The Rigaibat, the most powerful nomadic group in upper and middle Mauritania, form the basis of this case study. They are a tribe of remarkable solidarity, with a social structure that has attracted a great deal of interest. (9) They are grouped into two major divisions, the Lqacem (or eastern) and the Sahel (or western) Rigaibats. It is the pastoral pattern of the former that will be discussed here. Despite the fact that some scholars have contended that the pastoral activities of the Rigaibat take them everywhere in the western Sahara in a patternless pursuit of rainclouds, (10) nothing could be more at odds with the truth. Albeit somewhat less structured than the regularized patterns of southern Mauritanian pastoralists, the Rigaibat regime nevertheless involves regular, seasonal movements.

The areas occupied by the Rigaibat Lqacem are largely barren. The reg of Yetti is nearly devoid of wells, a circumstance making its use impossible except when winter rains cause the formation of rainpools. The same conditions apply to the Hamada of Tindouf, although Erg Iguidi, which bisects the Lqacem country, is surprisingly rich in wells. In contrast to the aridity of the central regs and hamadas, the peripheries of the Lqacem area are more elevated, and the wadis draining the slopes of al-Hank and Zemmour Labyad offer better possibilities for locating water throughout the year. Because of the wide expanses of land that are without vegetation during most of the year, a similarly wide disperson of friqs (the basic herding unit of five or six tents) is also common. This wide dispersion is apt to create an impression of irregularity. Although individual sections within the Rigaibat tribe have traditional areas of nomadization, in any one place in the Rigaibat territory, at any one time, a number of friqs from various sections may be found as individual tent groups follow their own best advantage. This pursuit of relative advantage is not without regularity, however, even though unusually bad years may force a departure from the normal regime and a concentration of friqs in the Wadi Draa of Morocco or in the better watered portions of central and southern Mauritania (11) - peripheral areas usually well beyond the normal zone of Rigaibat Lqacem grazing.

In winter, the various Rigaibat groups can be found around permanent watering points or shallow wells in Wadi al-Saquia al-Hamra, Wadi al-Ma, and Wadi Chenachane, along the flanks of the Zemmour Labyad and al-Hank ridges, or in especially favored hollows among the sand dunes of the Erg Iguidi. (12) During the summer, the friqs are concentrated in the wadi bottoms of the ergs, and the regs and hamadas are almost totally devoid of occupation. The distribution of herds and friqs remains unchanged until the first rains begin.

Once there is a definite rainfall, scouts are sent out to determine the precise part of the hamada in which the rainfall and resulting vegetation are best. (13) A variety of different moves, or no moves at all, are possible. If precipitation fails, the herder will move great distances to the very borders, or beyond the borders, of the tribal territory. If rain is especially abundant near the summer grazing areas or if the flock is composed of animals incapable of withstanding the rigors of long-distance migration, the nomad may not move at all. In general, however, assuming a year of average rainfall, there is a movement from the summer grazing areas on the flanks of the surrounding ridges into the hamadas and regs in the center. The precise area selected for winter grazing may vary from year to year, but the overall pattern of movement from summer wells to winter pasture in the interior desert remains unchanged. The area selected depends on whether that zone has received sufficient rainfall. (14) If so, friqs from different sections concentrate around the favored area.

In 1959, the most favored areas were around the wells of al-

Haiaina and Bou Ameima. Nevertheless, not all friqs went to the summer pastures in Yetti. A close check of the number of friqs present in the winter wadis (as shown in figure 1-1) indicates that nearly half failed to leave their winter locations. Admittedly, 1959 was a somewhat humid year, thus making local resources more attractive and perhaps reducing the desirability of moving. Also, the poor families, unwilling to face the potential risks involved in shifting their flocks to relatively unfamiliar territory, perhaps remained behind, while those possessing larger herds and greater ability to resist sudden catastrophe risked the migration. This points out the variation in patterns of movement that can be found within one tribe. The limited circulation of the poorer friqs around permanent water supplies and along the course of the wadi beds resembles the limited movement of the Kel Tamasheq.

The greater part of the winter is spent grazing the reg and hamada pastures until the wells, pools, and vegetation dry out and a return to the summer wells becomes imperative. During the stay at the winter pastures, the pastoral regime is complicated by the fact that the Rigaibat Lqacem, except for a few sections that are exclusively camel herders, own mixed herds of camels and sheep that are herded separately during most of the year. (15) The tents of each friq are pitched only a short distance apart and the milch camels, upon which the herding unit depends for its basic subsistence, are allowed to graze freely, under the care of the women, within a radius of three to six miles of the camp. However, the baggage camels and surplus female camels are placed under the care of the men and are herded separately from the milking herd; often these herds, representing the reserve wealth of the friq, operate at great distances from the family camp site. Most friqs also have a herd of sheep that is tended by the older children at a short distance from the camp site, to which they return twice each week to water the stock. It is quite common, therefore, for a substantial number of people and animals to be away from the friq at any time, thus conveying a false impression of small herds. This dispersal from and circulation around the actual tent site is greatest during the winter months when pastures are better and more widespread, but at all times the tent remains the focus of the pastoral system, and periodic return trips are made to the friq to water the stock. Thus, while the separate movements of the various herds during winter and summer grazing complicate the pastoral regime, they in no way detract from the essential regularity of the seasonal well-to-desert pattern of movement.

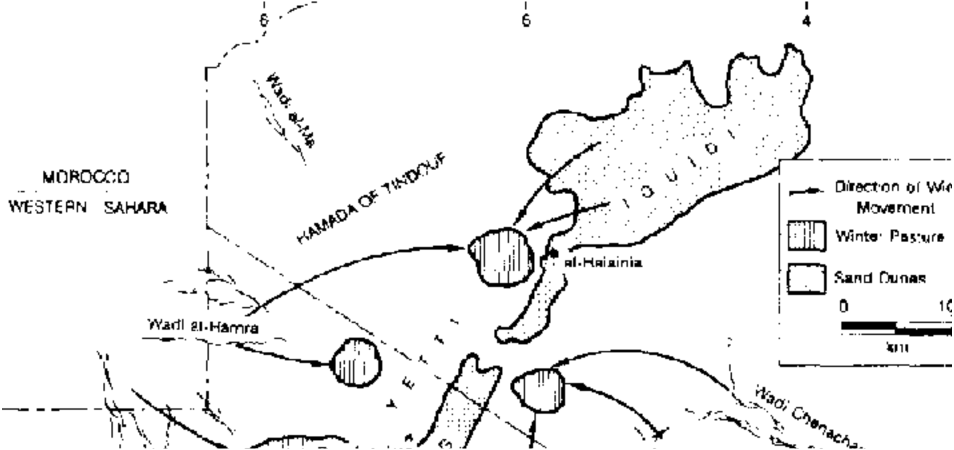

FIGURE 1 -1 Rigaibat Lqacem of northern Mauritania (after Bisson, 1963).

The Tribes of Southern Mauritania

In the broad stretch of territory extending from the Adrar to the southern border of Mauritania are found a number of different types of nomadic adjustments. Camels, sheep, goats, and cattle are all herded in this zone. Some tribes specialize in one animal, but tribal herds more often contain a variety of species, the exact mix depending upon complex balances among habit, tradition, the role of agriculture in the tribe's economy, political power and prestige, local variations in relief and climate, and other factors.

Camels are much more common in the arid north, where frequently they are the only animal herded. Their frequency and importance declines the nearer one comes to the more humid and disease-ridden regions along the Senegal River. Cattle, being less mobile, more demanding in their water requirements, and unable to utilize dune formations for forage, are found in greatest numbers in the south, where their ability to live on dry forage during the summer months makes them especially valuable. Sheep and goats are found everywhere, a function of their intermediate position between camels and cattle, for they are more mobile and more omniverous in their eating habits than cattle but less resistant to drought conditions than are camels.

Thus, groups with a greater proportion of camels than other animal species will cover longer distances in their annual migrations than will those tribes whose herds are largely composed of cattle. Also, tribes herding camels, sheep, goats, and cattle will, depending upon the size and importance of the different herding components, split their herds in an attempt to realize the optimal potential of each species.

In addition to these regularities in the areal distribution of animals and of the pastoral regimes that result from them, there is a distinct regularity in the latitudinal zones occupied by the Mauritanian nomads. During the hot, dry season, the herds and their masters are always concentrated in the southern portion of the Sahel zone, where numerous permanent wells supply water needs; in the rainy summer season, the tribes move northward to exploit pastures made green by the advancing tropical showers, and they usually remain somewhere in the northern portion of their tribal territory during the cool, dry season. (16)

The actual extent of northward penetration depends in part upon the adequacy of the rains, while in especially dry years many tribes, including the Rigaibat from the Saharan zone, can be found in the extreme southern part of Mauritania, where grass and water supplies are more assured. Also, most tribes have an association, either of reciprocity or domination, with an oasis or group of oases where they can obtain supplies of dates and grain, and this means that most tribes have a gatna (date harvest) period when they are back at the oasis for the harvest. (17)

Finally, while theoretically the need to water stock adequately is the only potential limitation upon migrations, in practice habit plays a large role in determining where a tribe will graze. (18) It is the return year after year to an area with well-known watering and grazing potentials that permits the delineation of tribal territories, and only dire necessity will force a tribe to move to an area outside its normal orbit.

In the most southerly parts of Mauritania, the fact that cattle and sheep form the basic component of the herds, coupled with the importance of cereal cultivation, keeps the extent and duration of pastoral movements small. (19) When the rains begin, the herders commonly make a short movement southward to pick up the rainfall at the earliest possible moment (20) and then follow the advance of the rains northward. Once the rainy season is over, the tribes return to their traditional summer wells, where they occupy a restricted area in close proximity to the watering point. Although the return is usually completed by October or November, some groups, for example the Ladem of the Hawd, (21) spend the cool, dry season at some intermediate point in the tribal territory.

Further north, the mixture of pastoral and agricultural forms becomes more complex. Some tribes are strictly camel herders, with little or no interest in agriculture. For example, the Ahel Noh spend the cool, dry season in the southern part of their area, the dry, hot season in an intermediate zone of sand dunes, and the rainy season on the edge of the Dar in the north. (22) The location of the dry, hotseason pastures in a zone intermediate between the pastures of the other two seasons is quite unusual, but actually represents merely an adaptation to peculiar locally favorable resources - in this case, the water resources collected at shallow depths beneath the dunes.

Most tribes, however, possess mixed herds. Those tribes herding sheep and camels divide the herds, with the sheep (and small herds of cattle, if these are owned) moving in restricted orbits in close proximity to the permanent watering points and agricultural centers of the section. Most of the family remains with the sheep and cattle herds. However, the camels, accompanied by shepherds and the young men, move in a completely different orbit and make use of this animal's superior mobility to range far into the interior. Whereas the herds of sheep follow a more fixed and definite route determined by the location of permanent watering points, the camel herders range more widely, visiting those places on their accustomed itinerary that have been especially favored by the season's rainfall. Just how long this move into the interior lasts differs from tribe to tribe.

Among the Ahel Saih Sidia, whose home wells are in the Awkar region, the movement of camels into the Inchiri region near Akjoujt lasts only during the rainy season; both the cool and hot dry seasons are spent in the southern Awkar, although during the cool season the tribe drifts south toward the wells, while at the end of the hot season they begin to move away from the wells in anticipation of the rainy period. (23)

On the other hand, the Ahel bou-Lobat (24) spend the rainy months moving slowly northward over relatively short distances, but once the rains cease they range far to the north into the Adrar, utilizing the dry but still nourishing pasture while the cool weather lasts. The Ahel bou-Lobat regime is complicated by the fact that the tribe owns palm trees at the oases of Dendane and at-Tiaiert and so must be present for the gatna season in July and August. Thus, their yearly cycle includes hot, dryseason camel camps midway between the two oases, a gatna move to the oases in July when all the herds are grouped together, a slow movement northward during the rainy season, a long loop into the Adrar in the cool season, and, finally, a southward return march to the hot-season camp site.

The combination of agricultural and pastoral activities is more complex among the Haiballah than in any other group. (25) Beginning with a gatna stop at al-Fejha in the Tamourt an-Naaj wadi (along the east side of the tribal territory), the Haiballah then move out onto the plateau during the rainy season. As they proceed northward and westward during the cool, dry season, they make stops at various agricultural areas to collect grain. Finally, as the hot season approaches, they move south into the acacia forest of Tamourt an-Naaj, where the leaves of the acacia trees form almost the sole pastoral resource during the hot, dry months. Yet, despite the importance of agriculture in determining where they are located at any time in the year, they remain essentially pastoral.

Along the coast, there is little agricultural activity, but the nomads participate in the general northward movement, parallel to the coast, during the rainy season and often also during the cool, dry season, (26) although some groups make a long move from Trarza deep into the Inchiri sand dunes. (27) Once the hot, dry season begins, a rapid southward shift takes place.

In conclusion, it seems significant that most of the nomads of southern Mauritania move in a roughly eliptical pattern. Occasionally, their outward and inward paths cross over each other, but it is more common for the herds to return to the dry-season wells by a route different from the one followed when leaving them. This difference in inbound and outbound routes is not commented upon in any of the literature, but it may be that the exhaustion of areas previously grazed during the year makes a selection of an alternative route desirable.

NOTES

1. Charles Toupet. "Quelques aspects de la sedentarisation des pomades en Mauritanie sahlienne," Annales de Geographie LXXIII(400):738-745 (1964).
2. Peveril Meigs. Geography of Coastal Deserts (Arid Zone Research No. 28, Paris: UNESCO, 1966), pp. 93-94.
3. For the physiography of northern Mauritania, see Jean Bisson, "La nomadisation des Reguibat L'Gouacem," p. 214; and Andre

Cauneille, "Les pomades Regueibat," Travaux de l'Institut de Recherches Sahariennes VI:83-84 (1950) .
4. Charles Toupet. "L'volution de la nomadisation en Mauritanie sahlienne," in Nomades et nomadisme au Sahara (Recherches sur la Zone Aride No. 19; Paris: UNESCO, 1963), p. 69.
5. Ibid., p. 69.
6. For the seasonal regime, see P. Borricand, "Le nomadisme en Mauritanie," Travaux de l'Institut de Recherches Sahariennes, V:81-83 (1948).
7. Toupet, "L'volution de la nomadisation en Mauritanie sahlienne," pp. 69-70; and E. J. Paris, "Notes sur les puits de l'Azaouad (Soudan)," Notes Africaine: Bulletin d'information et de correspondance de l'Institut Franais d'Afrique Noire, No. 53 (Janvier 1952), p. 24.
8. Cauneille, "Les pomades Reguibat," p. 85; and Borricand, "Le nomadisme en Mauritanie," p. 86.
9. David M. Hart, "The social structure of the Reguebat Bedouins of the western Sahara," Middle East Journal XVI:515-527 (1962), makes much of this solidarity. See also A. Leriche, Notes sur les

classes sociales et sur quelques tribus de Mauritanie," Bulletin de l'Institut Franais d'Afrique Noire, Srie B. XVII:173-203 (1955); and Modat, "Aperu sur la socit Maure de l'Adrar," Bulletin du Comit d'Etudes Historiques et Scientifiques de l'Afrique Occidentale Franaise V:264-278 (1922).

10. See, for example, Hart, ibid., p. 516.

11. Andre Cauneille and Jean Dubief, "Les Reguibat Legouacem: Chronologie et Nomadisme," Bulletin de l'Institut Franais de l'Afrique Noire, Srie B. XVII (1955).

12. Jean Bisson, "Nomadisation chez les Reguibat L'Gouacem," in Nomades et nomadisme au Sahara (Recherches sur la Zone Aride No. 19, Paris: UNESCO, 1963), p. 52, and map on p. 53; also idem, "La nomadisation des Reguibat L'Gouacem," p. 215, and map on p. 214.

13. Bisson, ibid., p. 52.

14. Bisson's maps (ibid., pp. 53-54; and "La nomadisation des Reguibat L'Gouacem," p. 214) point out the correlation between successive rainfalls in an area and its choice as a pastoral zone. However, since 0a data only deals with 1959 - an admittedly humid

year - there is no assurance that such overlap in rainfall occurrence is an absolute prerequisite for an area's selection.
15. Bisson, "Nomadisation chez lea Reguibat L'Gouacem," p. 53; and Borricand, "Le nomadisme en Mauritanie," p. 89.
16. M. F. Bonnet-Dupeyron, Cartes de l'Elevage en Mauritanie: Dplacement saisonniers de. leveurs en basse et moyenne Mauritanie (Carte 1/500,000, en 2 feuilles: Ia-Ouest, et Ib-est; Paris: ORSTOM, 1950). These maps are an often quoted source for the pastoral regime of southern Mauritania, and they point out this pattern clearly. Although cluttered and often confusing, they remain the most detailed work on the southern half of the country. For other general statements on the regime, see Borricand, "Le nomadisme en Mauritanie," pp. 86-87; and Toupet, "L'evolution de la nomadisation en Mauritanie sahlienne," pp. 69-70.
17. Ibid., p. 70; and Capot-Rey, "Le nomadisme pastoral," Nomades et nomadisme au sahara (Recherches sur la Zone Aride No. 19; Paris: UNESCO, 1963), pp. 72-73.
18. Borricand, "Le nomadisme en Mauritania," p. 87.
19. See Paul Marty, Etudes sur l'Islam et les tribus Maures: Les

Brakna (Collection de la Revue du Monde Musulman; Paris: Ernest Leroux, 1921) an example of these limited movements in the Brakna area.
20. Capot-Rey, Le Sahara franais, in L'Afrique blanche franaise Paris: Presses Universitaires de France) II :2 59; and Borricand , "Le nomadisme en Mauritanie," p. 86.
21. Toupet, "L'volution de la nomadisation en Mauritanie sahlienne," p. 73.
22. Ibid., p. 71.
23. Paul Dubie, "La vie matrielle des Maures," Mlanges Ethnologiques (Mmoires de l'Institut Franais d'Afrique Noire, No. 23; (Dakar: IFAN, 1953), pp. 122, 139.
24. Toupet, "L'volution de la nomadisation en Mauritanie sahlienne," p. 72.
25. Ibid., pp. 74-75.
26. Bonnet-Dupeyron, Carte de ;'Elevage en Mauritanie (Ia-Ouest).
27. Capot-Rey, La Sahara franais, pp. 258-259.

The Beni Mguild of Morocco

DOUGLAS L. JOHNSON

Deciding just how nomadic or sedentary a particular tribal group in rural Morocco is poses a major problem, for nearly every possible combination of nomadism and agriculture can be found from group to group and often within one group itself. Consider, for example, the At Atta on the Saharan side of the Atlas, some of whose subgroups are fully nomadic, (1) while others are either partially sedentary or are only partially nomadic. (2) It is also common for sedentary agriculturalists to keep animals as a means of using otherwise unexploitable areas and engaging in transhumant movements to bring these animals to better seasonal pastures. (3) Indeed, as Blanche points out, (4) all sedentaries keep some animals and all nomads do some supplementary farming, so that "pure" nomadism hardly exists. It becomes quite difficult, therefore, to determine what group is essentially nomadic unless primary weight is placed upon the relative importance of the role played by animal husbandry and agriculture within the tribal economy.

With this criterion in mind, it seems fair to say that the subjects of this case study, the Beni Mguild of central Morocco, are essentially a nomadic group. For while the pastoral-agricultural regime of the Beni Mguild has frequently been described as a double transhumance (5) in which the cultivation of cereal crops plays a large role, it is the necessity to shift their herds of sheep and goats between various altitudinal zones at different seasons of the year that gives the Beni Mguild Arabs their highly involved migratory pattern.

This is not to deny the importance of agriculture, but the herds are the primary source of wealth, and as such, claim priority in the system of movement. This fact is amply demonstrated by the marked decline in the size of all herds after the French penetrated the Moulouya Valley and restricted the Beni Mguild's seasonal movements. (6) Precisely because agriculture is a prominent part of their system and because they make so many moves in order to exploit as fully as possible their rugged upland environment, the Beni Mguild offer great insight into the adaptive nature of pastoral nomadism.

Physical geography

The tribal areas of the Beni Mguild are located in the central portion of the Middle Atlas and can be divided into three zones: (7) the Azaghar Plateau region, the ridges of the Middle Atlas proper, and the steppes of the Upper Moulouya Valley. The Middle Atlas range dominates the region. Aligned in a southwesterly to northeasterly direction, the Middle Atlas is a broken, mountainous area running from the High Atlas to an abrupt termination near Taza. At its southern end, the range drops rapidly to the Plain of Tadla on its western side, while it runs parallel to the High Atlas on its eastern side. It is separated from the High Atlas by the deep gorge of the Wadi al-Abid. This dividing line is more than simply a physical separation, for in the more arid areas south of the High Atlas, the Ait Atta practice a form of nomadism that differs notably from that of the Beni Mguild. (8) North of the Wadi al-Abid, the Middle Atlas trends in a more westerly direction, and the wedge-shaped upper and middle Moulouya plains intrude between the two ridges. Here, the eastern boundary of the Middle Atlas is marked by an abrupt descent into the Moulouya Valley. Boundaries for the Middle Atlas peaks, some of which exceed 2,500 m and many of which are important summer grazing areas for the herds of the Beni Mguild, are much less clear on all other sides, particularly to the northwest, where the ground gradually drops off through plateau country as it slopes gently toward the ocean.

This gently sloping upland is called the Azaghar Plateau. (9) Bounded by an abrupt drop to the Sas Plain near Mekns on the north, the Plain of Tadla and the fields along the Wadi Oum ar-Rbia on the southeast, and the cliff of Zaiane on the west, the plateau has geographical unity despite its gradual blend into the Middle Atlas. Averaging about 1,200 m in elevation, the surface of the Azaghar Plateau is dotted by a series of old volcanic cones, is cut by an intricate web of narrow valleys providing access to the area, and contains a significant number of smaller plateaus that vary quite considerably from the general elevation of the Azaghar. Both the

Azaghar and the Middle Atlas are drained by a number of streams and wadis, whose courses parallel the trend of the mountains in their headwater portions, but later turn west to break through the mountains on their way to the ocean, and in so doing open up routes for passage through the mountains. It is this complex series of plateaus, old volcanic cones, and narrow valleys that forms the winter grazing territory of the Beni Mguild.

The third physiographic zone, the plain of the Upper Moulouya, is a steppe region that contrasts markedly with the mountain and upland areas to the west. Southeast of the town of Itzer, a very steep cliff emphasizes the abrupt change in elevation between the Middle Atlas and the Moulouya steppe. Here, a number of small streams tumble down out of the mountains, supporting the small agricultural villages and fortified granaries that dot these valleys. (10) West of Itzer, the slope from the Atlas into the plains is more gradual, and agricultural possibilities are more limited.

As Clrier points out, (11) it is climate, acting upon the physiography and the distribution of vegetation, that plays a key role in the Beni Mguild's adjustment to and exploitation of their environment. As is the case with much of the mountainous area of North Africa, Morocco is dominated by the Mediterranean regime of summer drought and winter precipitation. The eastward drift of cyclonic storms from the Atlantic encounters the barrier of the Middle Atlas; being forced to rise, the storms deposit considerable quantities of precipitation in the area. In the lowlands, this precipitation falls as rain, but on the higher peaks (over 2,200 m) snow is the rule and the snow cover here lasts all winter. The Azaghar Plateau, occupying an intermediate position, receives rain and snow, but its elevation is sufficiently low that snowfalls rarely result in significant accumulations. This winter snowfall is crucial, because the quality of the summer pasture depends upon the adequacy of the snowfalls (12) Although occasional violent thunderstorms bring some precipitation to the uplands, pasture is dependent upon snow melt for its nourishment. However, at the same time that snow is falling in the high Middle Atlas and blocking all winter movement of man and beast across the mountains, the absence of snow in the lower elevations is an essential prerequisite for the successful winter pasture of the Beni Mguild in the Azaghar.

Vegetation shows a vertical zonation similar to the distribution of rain and snow. (13) Cedar (Cedrus atlantica) is found on the higher slopes of the more humid northern and central portions of the Middle Atlas. The distribution of the cedar begins at about 1,300 m and extends upwards to the snow line at about 2,200 m. However, above 2,200 m regeneration is difficult; hence, an herbacious vegetation nourished by snow melt emerges in the spring. Downslope from the cedars is the zone of evergreen oaks and occasionally of thuya (Callitris articulata), which is frequently degraded by cutting, browsing, and burning into a maquis assemblage. Numerous grasses and agricultural stubble, important for foraging, are found below 2,000 m. On the eastern slopes of the Middle Atlas, the entire character of the vegetation changes, for the rainshadow effect of the mountains favors the development of a steppe complex, where esparto (Stipa tenacisima) - a tough tussock grass, inedible during most of the year - is most common.

The natural regime sketched above is one of distinct seasonal and altitudinal variation in the availability of pasture and water. In summer, agriculture engages the attention of tribesmen in lowland and plateau areas, and the herds are kept in the upland areas over 2,200 m to take advantage of pastures nourished by melting snow or the esparto of the Moulouya Valley. In winter, herds are moved to the lowland plateaus of the Azaghar, where milder temperatures and adequate rainfall permit abundant grazing on unoccupied land or harvested fields. Actually, as indicated below, the system is still more complex, for the Beni Mguild are engaged in cereal farming in the Moulouya Valley at the same time that they are shifting their herds from zone to zone.

Migratory cycle

The Beni Mguild are divided into two major groups, a northern and a southern, and it is the migratory pattern of the southern group that is considered here (figure 2-1). The southern Beni Mguild are, in turn, divided into four separate subtribes, each with its own slightly different adjustments, migratory routes, and areas of cultivation and pasturage. The northernmost of these subtribes, the Ait Lias, begin their seasonal cycle south of Itzer, while the larger Ait Ougadir (the Ait Quebel Lahram and Ait Ali) are strung out along a series of small streams descending the steep eastern face of the Middle Atlas. (14) The remaining two subtribes, the Ait Bougueman and the Ait Messaoud, are spread out widely in the wedge-shaped portion of the Upper Moulouya on both sides of the river and in the gorges of the ancient Massif of Aouli. (15)

October is taken as the starting point of the yearly cycle both for convenience and because it marks the end of the Beni Mguild's agricultural activities. (16) In October, the various Beni Mguild sections can be found in the Upper Moulonya attending to their cultivated fields on the steppe. Once the harvest is completed and stored in fortified granaries, it becomes necessary to move to the Azaghar Plateau, as pasturage in the Upper Moulouya is insufficient for all the flocks. This move to the Azaghar begins about the first of November and continues throughout most of the month. Movement is slow and follows a regular order from the southeast toward the northeast with one group of tents packing up and leaving only to be followed immediately by another douar, or village of tents, moving successively into the abandoned pasturage. (17) The nomads always travel in substantial groups, or caravans, to prevent any interference with their progress by other nomads or by sedentary villagers along their route.

The Ait Lias go first, travelling through the pass at Tizi Zad (on the main Mekns to Midelt road) to their traditional pastures around Azrou and Ifrane, (18) although some have been reported as far west as al-Hajeb. (19) Slightly later, the Ait Ougadir cross the first mountain barrier at Tizi-n 'Rechou and at a point somewhat farther north before turning northeastward up the synclinal valley of the Wadi Serrou. After skirting Jabal Tamarakoit, Jabal Hayane, and the slopes around Aguelmane-Azigza, they pass through Ain-Leuh on the way to their winter pastures in the Plateau of Tellt between Wadi Beth and Wadi Aguennor. (20) A similar route is also followed by the Ait Bougueman and Ait Messaoud, who have long taken the same path as the Ait Ougadir. They also winter on the Plateau of Tellt as well as in the plains of Messouar and Guertila and on the Plateau of Ment. At one time, various sections of the Ait Bougueman and the Ait Messaoud seem to have fallen under the authority of the Zaiane tribe to their immediate south, thus permitting them to take slightly more southerly routes to their traditional pastures, (21) but this evidently represented a departure from the more normal pattern.

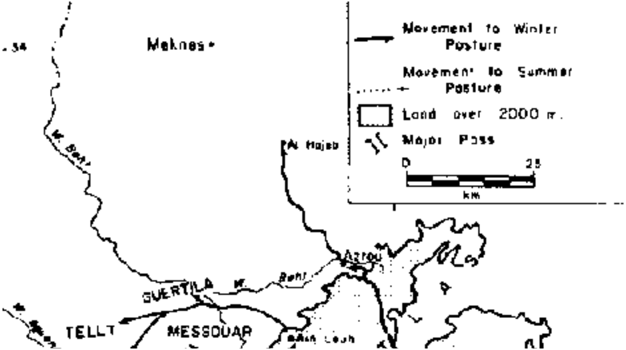

FIGURE 2-1 Arabs of the Middle Atlas (after Clrier and Joly). (5)

Although the Azaghar is occupied by other nomadic groups during the summer, these groups withdraw toward the coast during the winter and, except for the agriculturists, the Azaghar is left to the Beni Mguild. (22) The Azaghar is occupied throughout the winter months; the herds utilize the pastures made rich and verdant by the winter rains. Once the snow is melted at the passes, usually about the beginning of March, and movement back to the Moulonya Valley becomes possible, the Beni Mguild leave the Azaghar. They retrace their steps, following the same route in March as they did in November; this migration usually takes an entire month.

By April, the Beni Mguild are back in the Moulonya Valley. Their tents are dispersed along the edges of the irrigated fields and their animals are pastured in the fields, thereby providing fertilizer for the next agricultural cycle. (23) At the end of the month, the fields have been planted and the Beni Mguild are ready to move once again. This time, the movement is toward the high mountain pastures made available by the melting snow, for with the steppe either planted in cereals or drying up, and with the Azagher occupied by peasant agriculturalists or other nomads, only the upland pastures, over 2,200 m, remain to be exploited.

These mountain pastures are divided in the same way as the lowland pastures, and each tribe knows what area is assigned to it and what forest areas are open to its animals. (24) In the beginning of July, the herds move out, crossing into Wadi Serrou and then turning north to Aguelmane-Azigza and the slopes of Jabal Tamarakoit in a repetition of the initial stages of their winter moves. (25) May and June are spent in carrying out this move with the herds grazing slowly upslope through the forests, much to the chagrin of the forest service. Only the Ait Messaoud fail to participate fully in this movement. Driven from the Moulonya Valley by the desiccation of its pastures, the Ait Messaoud, like the rest of the Beni Mguild, send many of their herds to the northern slopes and plateaus of the High Atlas where, shaded from the full impact of the sun's rays, adequate pasturage can be found. (26)

Not everyone follows the herds to the upland pastures, since someone must stay behind to guard the family fields. The Beni

Mguild possess both large- and small-size tents, and it is the size of the tent accompanying the herds, as opposed to the size of the tent remaining behind on the agricultural fields, that indicates the relative importance of herding activities. (27) Among the Ait Ougadir, the large tent goes with the herds into the mountains, whereas the small tent remains behind near the agricultural fields; the situation is reversed among the Ait Bougueman and the Ait Messaoud. The herds and their keepers remain in the upland pastures through July and August, albeit with occasional movement of individuals between the mountains and the Moulonya Valley. In mid-September, (28) increasingly cool temperatures and the need to harvest the cereal crop lead to a rapid movement of herds and population back along the way they came, and hence into the upper Moulouya Valley by October.

The system described above is complex. Although the distances covered are not excessive (the distance from the upper Moulouya Valley to the Azaghar is only about 100 km in a straight line, but of course is longer via the nomads' route), they are extensive enough to make permanent housing impractical for the majority of the population. In every instance, the direction of movement is perpendicular to the mountain chain and utilizes streambeds and the passes between them to move from valley to valley en route to the desired pasturage zone. This gives the pattern of movement the highly constricted linear appearance characteristic of mountain nomadism. Although the Beni Mguild's pattern is more complicated than the usual oscillation between highland and lowland pasture found in mountain areas, this represents an adaptive utilization of an unusual juxtaposition of mountains, plains, and plateaus, rather than an entirely new type of pastoral exploitation.

NOTES

1. An excellent study of an Ait Atta section is found in Fernand Joly, "Les Ait Khebbache de Taouz (Maroc Sudoriental)," Travaux de l'Institut Recherches Sahariennes VII:129-159 (1951).
2. D. G. Jongmans and J. H. Jager Gerlings, Lea Au Atta. Leur Sedentarisation No. 115 (Amsterdam: Institute Royal des

Tropiques, 1956) and No. 50 (Amsterdam: Dpartment d'Anthropologie Culturelle et Physique, 1956). See also G. Marcy, "Une tribu Berbere de la Confederation des Ait Warain: les Ait Jellidasen," Hsperis lX:79-142 (1919), for a similar situation among the Berber tribes near Taza.

3. Jean Dresch, Commentaire des cartes sur les genre, de vie de montagne dans le massif central du Grand Atlas, (Publications de l'lnstitut des Hautes Etudes Marocaines; Tours: Arrault, 1941), XXXV:1822, shows how intricate and involved these upslope-downslope movements can be. See also Dresch, "Migration pastorales dans le Haut Atlas calcaire (Regions de Dennat et d'Ouaouizerth)," Mlanges gographiques offerts a Ph. Arbos (Clermont-Ferrand: G. de Bussac, 1953), pp. 131-140.

4. Jules Blache, "Modes of Life in the Moroccan Countryside: Interpretations of Aerial Photographs," Geographical Review X1:482 (1921).

5. Jean Clrier, "La transhumance dans le Moyen-Atlas," Hespris, VII:64 (1927); Fernand Joly, "Elevage: Ovins et Caprins," Atlas du Maroc: notices explicatives (Comit de Gographie du Maroc, Section

X - Geographie Economique, Elevage, Planche No. 40a; Rabat: Comit de Gographie du Maroc, 1954), p. 54; and E. Laoust, "L'habitation chez les transhumants du Maroc Central: I, La tense et le douar," Hespris X:246 (1930).
6. Ren Raynal, "La terre et l'homme en Haute Moulouya," pp. 487-500, points out the results of French interference that resulted in the sedentarization of most of the Ma'qil Arabs on their agricultural holdings in the Moulonya. In the case of the Ait Messaoud and the Ait Bougueman, two subtribes of the Ma'qil Arabs, herds declined from over 200,000 sheep at the height of pastoral movements to 45,000 today. See also, idem Dplacements rcents et actuels des populations du Bassin de la Moulouya (Maroc Oriental)," Comptes Rendus du Congres international de Gographie, Lisbonne, 1949 (Lisbonne: 1952), IV:67-80.
7. See Pierre Birod and Jean Dresch. La Mediterrane et le Moyen-Orient (Paris: Presses Universitaires de France, 1953-1956), 1:436-439; and Jean Despois, L'Afrique du Nord (Paris: Presses Universitaires de France, 1949), pp.52-56.
8. Jean Clrier, "La transhumance dans le Moyen-Atlas," Hesperis

Vll:53-68 (see p. 55) (1927).
9. E. Laoust. "L'habitation chez les transhumants du Maroc Central 1, La tense et le douar," Hespris X:151-253 (1930) points out, the term azaghar means a specific geographic region, but it carries with it numerous other connotations such as small village, fields, grazing for animals, etc.
10. For the Upper Moulonya, see Raynal, "La terre et l'homme en Haute Moulouya,- pp. 489-490.
11. Jean Clrier, "La montagne au Maroc (Essai de definition et de classification) ," Hespris XXV: 109180 (1938) .
12. Clrier, "La transhumance dans le Moyen-Atlas," p. 56; and Laoust, "L'habitation, I," pp. 152-153.
13. See J. Martin et al., Gographie du Maroc (Paris: Hatier; Casablanca: Librairie Nationale, 1964), p. 123, map on p. 120. Also valuable are Birot and Dresch, La Mediterrane et le Moyen-Orient, 1:436-439; and Despois, Jean, L'Afrique du Nord, pp. 86-95.
14. Clrier, "La transhumance dans le Moyen-Atlas," p. 64.
15. Raynal, "La terre et l'homme en Haute Moulouya p. 491; and Clrier, "La transhumance dans le Moyen-Atlas," p. 64.

16. For the clearest and most concise account of the yearly cycle, see Jean Clrier, Maroc (L'union franaise; Paris: Editions Berger-Levrault, 1948), p. 90. Also extremely valuable is the map and schematic representation in Joly, Atlas du Maroc, p. 26, and the route descriptions in the new classic article by Clrier, "La transhumance dans le Moyen-Atlas," pp. 64-67. A more general work treating the Ma'qil Arabs is Suzanne Nouvel, Nomades et sdentaires au Maroc (Paris: Emile Larose, 1919).17.Laoust, "L'habitation...I," p. 241.
18. Clrier, "La transhumance dans le Moyen-Atlas," p. 65; and Martin et al., Gographie du Maroc, p. 129.
19. Laoust, "L'habitation...l," p. 243.
20. Clrier, "La transhumance dans le Moyen-Atlas," p. 65.
21. Ibid., p. 66.
22. Walter B. Harris,"The Nomadic Berbers of Central Morocco," Geographical Journal 1X:639 (1897); and Nouvel, Nomades et sdentaires au Maroc, pp. 58-59.
23. Clrier, Maroc, p. 90.
24. Nouvel, Nomades et sdentaires au Maroc, p. 57.

25. Clrier, "La transhumance dans le Moyen-Atlas," p. 64.
26. Ibid., p. 65.
27. Laoust, "L'habitation...l," p. 249; and Clrier, "La transhumance dans le Moyen-Atlas," p. 65.
28. Joly, Atlas Mu Maroc, p. 26.

The Kel Tamasheq

SUSAN E. GUNN

Introduction

The following is based on nine months of fieldwork undertaken by the author in southern Mali among the nomadic Kel Tamasheq (Tuareg). Most of this time was spent with the Oulliminden tribe, which inhabits the area between Gao on the Niger River and the Niger border. These people are one of the most isolated of the Kel Tamasheq groups; the lack of outside influence is reflected both in their material culture and diet.

The Kel Tamasheq's physical setting borders the southern Sahara and is known as the West African Sahel. This region is characterized by an annual rainfall of 15-150 mm, which allows the survival of a vegetation pattern dominated by annuals such as Cenchrus biporus and Tribulus terrestris and trees such as Balanites aegyptiaca and Acacia spp. The fauna include Gazella dorcas and G. dama, as well as the ostrich, warthog, and giraffe, although these wild populations have been drastically reduced in recent years because of the use of motorized vehicles and firearms (Nicholas, 1950; Richer, 1924). Three seasonal extremes can be distinguished: a cold, dry period from December through February; a hot, dry period during April and May; and a wet season beginning in mid-June and lasting until September, during which violent storms and the only measurable precipitation during the year occur. Temperatures during the day reach highs of 46°C (115°F) in May and at night may dip as low at 4.5°C (40°F) in December. The Sahel dwellers have adapted to this environment by utilizing almost all natural resources, either directly or through the medium of animals, and have obtained them in amounts sufficient to sustain life by moving from area to area.

The nomads do not form a homogeneous society, although they have a common designation as Kel Tamasheq (Tamasheq speakers) or Kel Esuf (people of the bush). Many authors have used the Arabic term "Tuareg" in referring to this group, but since it is sometimes used to refer only to noble classes and because the nomads never use it, their own designation for themselves, Kel Tamasheq, will be followed. Recently, non-Tamasheq speakers have been moving into this area, mainly Peul (Fulani) and Arabs. The pattern of adaptation of the Arabs is very similar to that of the Tamasheq, but the Peul lifestyle differs considerably. The Tamasheq comprise five distinct social categories: nobles (known as imajaren), their vassals (for example, imrad, debakar, chamenamas), marabout tribes (Kel Essouk), slaves (iklan or bella), and artisans (inadan). Slaves and artisans may reside either independently or, as is traditional, in the camps of the wealthier nobles, vassals, and marabouts; the latter three groups may visit each other for long periods but do not live together permanently.

Details of occupation, ritual, physical type, and kinship patterns vary among these groups but on the whole, their adaptation to their environment is quite similar (N'Diaye, 1970). All are pastoralists with herds including camels, cattle, sheep, and goats (as well as household animals including donkeys and dogs); they are traditionally "pure" nomads (that is, never sedentary); they are Muslim and speak a common language, Tamasheq.

Diet

Although diet varies according to the season and to the wealth age, and social position of the individual, milk - either fresh or soured - is the basic food for all. To make sour milk, a culture is placed in fresh milk (preferaby cow's), which is allowed to stand for 14 hours. It then may be drunk plain, or with the addition of water, the dried and pulverized fruit of Ziziphus spp., flour of millet or wild grains, cheese, or dates. The preparations, translated as "crme," are considered to be very fortifying. Butter is made from cow's milk and is churned in a goatskin each morning. Cheese is made only during the rainy season when there is a surplus of milk; after drying, it can be kept for more than a year. Donkey's milk is used only for medicines.

Animal	Nobles (Imajaren) (5 households)	Iklan for Cows (7 households)	Iklan for Camels (5 households)	Artisans (4 households)
Camels	3.0	0	3.5	1.3
Cows	2.4	3.2	0	4.0
Goats	0	9.0	5.0	6.0
Sheep	0	+	0	0

*Ratio changes as new animals are born.
+Only 1 household has lactating sheep (10).

TABLE 3-1 Average Number of Lactating Animals per Household, According to Social Class and Animal Type (Example Drawn from One Camp in June 1972) *

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Cows	2.4	3.2	0	4.0
Goats	0	9.0	5.0	6.0
Sheep	0	+	0	0

*Ratio changes as new animals are born. +Only 1 household has lactating sheep (10).

TABLE 3-2 Approximate Yields of Milk According to Animal Type at Evening Milking (in liters).

Animal	Cold Season	Hot Season	Wet Season	Times milked per 24 hours
Camel	5-7	2-4	7-9	3

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cow	3-4	2-3	4-7	2
Goat	0-1/2	1	2	2
Sheep	2	0	3	1

In principle, the milk supply available to each family at any one time should vary according to the number of milk animals it owns, or (as in the case of iklan), the number allotted to it; and the type of animals, since this determines when lactation begins, how long it continues, and the amount produced (tables 3-1, 3-2, and 3-3). (An individual family is likely to have only one or two types.) However, these social and economic variations are minimized through a system of redistribution operating both among the households and among the social categories within the camp. The common mechanisms are trading (for example, tobacco for milk, camel's milk for cow's milk), sharing, and "stealing." Imajaren households are an exception, because they cannot share the milk itself with others of the same rank but may instead either borrow a lactating animal or send their children to drink with a family that has a surplus.

Animal	Months Gestation	Months between Gestations	Births per 2 Years	Months Lactation
Camel	12	10-12	1	18-24
Cow	10	2-4*, 12**	2	10-15
Goat	5	2	8 (twins)	7-8
Sheep	6	2*	6 (twins)	7

*If pasture is extraordinarily good
**If pasture is extraordinarily bad

TABLE 3-3 Lactation Patterns According to Animal Type

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Animal	Months Gestation	Months between Gestations	Births per 2 Years	Months Lactation
Camel	12	10-12	1	18-24
Cow	10	2-4*, 12**	2	10-16

Cow	10	2-4, 12	2	10-16
Goat	5	2	8 (twine)	7-8
Sheep	6	2*	6 (twine)	7

*If pasture is extraordinarily good
**if pasture is extraordinarily bad

Except during the wet season, milk is insufficient to nourish adults and therefore is supplemented with wild and domesticated grains. The wild grain gathered by the slaves and poorer vassals, consists primarily of Panicum laetum spp. (ishiban, which can be further separated into akasof and asral) and Cenchrus biflorus (wajag) (see table 3-4 for additional species). Panicum is the most important wild grain because it is more abundant, is the first to ripen after the rains, requires very little preparation (pounding), and does not cause digestive upsets. It is harvested at three different stages in the ripening process: the first, beginning in August or September, lasts only 10-15 days and involves cutting the heads from the standing grain. This harvest is especially important if the milk supply is low. The second follows in mid-September when the grain is ready to fall; the stalks are bent over a basket and the grains beaten into it. This ishiban is considered the cleanest and is most preferred. The final harvest begins in October and lasts until the next rains in June or July; it consists merely of sweeping up seeds that have fallen naturally after the dry grass has been cut or eaten by animals or burned off. Grain gathered in this manner is considered to be of lowest quality, since it requires considerable preparation before eating to remove the sand. After harvesting, the grain is dried and stored in leather sacks, mud-brick granaries rented in towns, or in holes in the sand (0.5 m in diameter and 1.5 m deep) lined with matting. Grain that is stored in this latter fashion is usually conserved for times of scarcity. When the first harvests come in (September), these reserves are immediately replenished and whatever old grain remains is either eaten or sold. The grain is said to suffer little loss in quality for at least two or three years. The location of the holes is secret but they often are placed near the wells frequented by the group, beside the stands of grain, or on the edge of a village. (Table 3-5 lists the harvest periods of the primary grains.)

Name of grain	Collection	Preparation	Importance or use
Asaral*	Aug-June in watered plateaux and valleys by Iklan or Imrad	Cooked always needs sauce (milk or butter)	First grain to ripen; very light no diseases; "good for diarrhoea."
Akasof*	Drier plateaux, is smaller than Asaral		
Tegebart	Found in same places as Asaral, often mixed	Cooked or raw as "creme", does not need sauce	Is considered to be the best variety of ishiban
Wajag	Needs heavy rain before growth starts, must wait till straw is dry before gathering--by an Iklan on dunes and plains	Cooked or raw as "creme"	Considered more nutritious than ishiban; was main feed for horses with milk. If eaten excessively, can give diarrhoea
Agarof	During wet season when still slightly green on dunes	Pounded to break off spines (vicious!); cooked or raw	Flavourful, especially "good for old people as tonic, and blood diseases"
Afaso	On dunes in same areas as ishaban during October	Harder to pound than ishiban' raw or cooked	Can be found in great quantities but only harvested if ishiban lacks--famine food low status

Tajite	A red grain found in clear spaces after a rain, collected by ants, can be scraped up with hands	Difficult to pound; cooked or raw	One of the few grains available at this time "keeps stomach full till next day; good for men"

*Asaral and akasof are both called ishiban

Grains		Fruits:	
Asaral	= *Panicum laetum* Kunth	Amalaja	= *Acacia raddiana* Savi
Akasof	= *Panicum laetum* Kunth	Tadant	= *Acacia senegalensis* Lamk
Tegebart	= *Echinochloa colona* Link	Abora	= *Balanites aegyptiaca*
Wajag	= *Cenchrus biflorus*	Terakot	= *Grewia populifolia* Vahl.
Agarof	= *Tribulus terrestris*	Tabakot	= *Ziziphus saharae*
Afaso	= *Panicum turgidum*		
Tajite	= *Eragrostis sp.*		
Vegetables:		Gums:	
Eshako	= *Glossonema boveanum*	Tamat	= *Acacia seyal* Del
Agar	= *Maerua crassifolia*	Afaja	= *Acacia raddiana* Savi
Tagoyo	= *Citrullus colocynthis* Schrad		
Alikid	= *Citrullus colocynthis* Schrad		
Ibel awent	= *Rumex*?		
Abedebit	= *Boerhavia agglutinans*		
Tomasalt	= *Limeum indicum* Stocks		

TABLE 3-4 Commonly Used Wild Grains and Other Wild Foods

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Asaral.	Aug-June in watered plateaux and valleys by Iklan or Imrad	Cooked always needs sauce (milk or butter)	First grain to ripen; very light; no diseases; "good for diarrhoea."
Akasof.	Drier plateaux is smaller than Asaral		
Tegebart	Found in same places as Asaral, often mixed	Cooked or raw as "creme"; does not need sauce	Is considered to be the best variety of ishiban
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	up with hands	stomach full till next good for men"	

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Wajag = Cenchrus biflorus	Terakot = Grewia populifolia Vahl.
Agarof = Tribulus terrestis	Tabakot = Ziziphus saharae
Afaso = Panicum turgidum	
Tajite = Eragrostis sp.	

Vegetables:	**Gums:**
Eshako = Glossonema bovennum	Tamat = Acacia seyal Dil
Agar = Maerus crassifolis	Afaja = Acacia raddiana Savi
Tagoya = Citrullus colocynthis Schrad	
Alikid = Citrullus colocynthis Schrad	
Ibellawent = Rumex	
Abedebit = Boerhavia aggulutinans	
Tamasalt = Limeum indicum Stacks	

Domestic grains (wet rice, millet, and occasionally sorghum) that are grown by sedentary agriculturists along the Niger River were traditionally supplied to the nomads as tribute, but now the nomads purchase them when the wild grains are unavailable or for special occasions. Domestic forms constitute roughly half of the grain eaten by nobles, but only a quarter for the iklan, although this depends on the size of the harvests. During the months from September to

January, ishiban and wajag are eaten by everyone, but as the supplies diminish, the wealthy nomads and imajaren eat an increasingly greater proportion of domesticated grains, whereas the poorer people resort to the less common wild grains, for example, Tribulus terrestris (agarof), as shown in table 3-6.

Both domestic and wild grains are pounded in a wooden mortar to remove the bran; it is then separated from the grain by shaking from one flat basket to another, the process also used for removing sand. No stone querns, pestles, or grinding stones were observed among the Tamasheq in the Sahel, although Nicolaisen (1963) and Gast (1968) note their use in the northern Sahara. The bran is frequently given to slaves and is eaten either raw or cooked. The cleaned grain is boiled in open metal pots, then eaten with butter, pounded meat, or sour milk and salt.

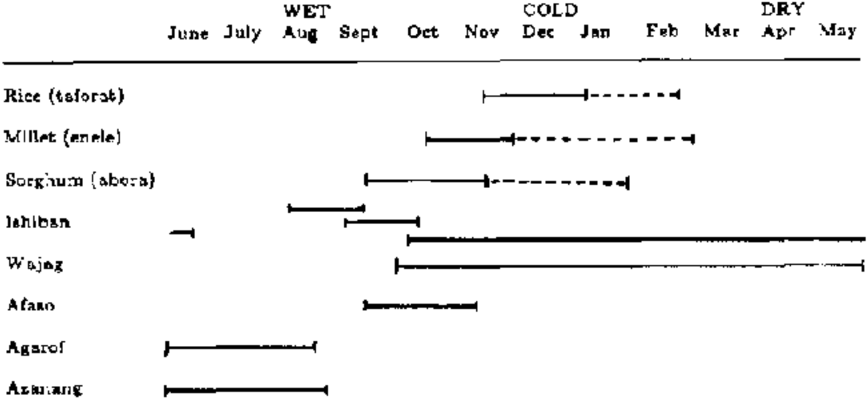


TABLE 3-5 Harvest Periods of Major Domestic and Wild Grains

Vegetables are consumed mainly when other foods are scarce, or by children of lower status groups. This is largely due to prohibitions against eating them (held by higher class Tamasheq, as well as by the slaves and artisans who live with them), and perhaps also to their relative scarcity in the Sahel. Vegetables are usually cooked in water, although the melons (tilagarien) may be roasted in hot ashes. Some (for example, tatola) are eaten raw, but this is rare.

Fruits are generally taboo, although small dried berries of Ziziphus Spp. (tabakat) and Grewia tenax (terakat), which are gathered by iklan during August and September, are sometimes used as a sweetening for sour milk. Iklan and artisan children also collect and enjoy "desert date" (aborak) and the gums of several trees. Aborak is the fruit of Balanites aegyptiaca, and not of the wild Senegal date palm, P.reclinata. The fruit of the domesticated date palm, P. dactylifera, are also used for sweetening, but they are scarce; they are not found in the Sahel, but are acquired through trade with northern oases dwellers. Some leaves that are used as medicines, Cassia obovata (agargar), for example, may impart some nutrition; they are usually chewed or brewed as tea. (Species of vegetables, fruits, and gums and the mode of preparation are listed in table 3-7.)

The imajaren are prohibited from eating fish and insects as well, but other groups, especially those whose nomadic patterns bring them close to the Niger River, eat fish. Use of locusts has been noted among the Tamasheq tribes of the Sahara by Foley (1930:209) and Gast (1968: 251).

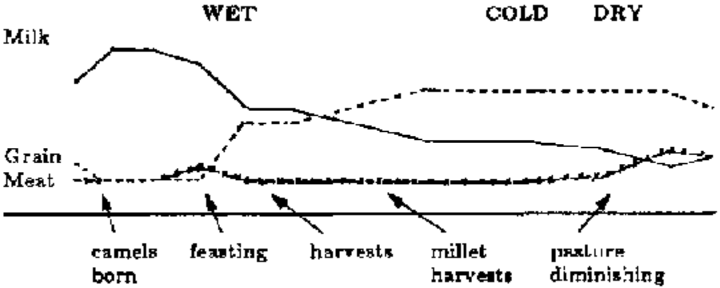


TABLE: 3-6 Proportion of Milk, Meat, and Grain in Diet According to Season

Name	Collection	Preparation	Importance or Use

Vegetables:

Eshako	At end of wet season, in stony ground	Pull off leaves and boil in water	Important food plant in barren areas
Agasse	Short plant found after rains beside lakes	Remove thick stems, boil leaves in water	Eaten in great quantities by children
Ahowat	Parasite growing usually on (Acacia tortilis or A. laeta	Eaten raw (leaves), never cooked, slightly bitter	
Agar	Leaves of tree are picked by iklan	Must be cooked twice; or discarded	Not very tasty, only for emergencies
Tatola	Thick woody vine that grows up trees, after rain	Root eaten raw, leaves eaten or roasted	A sweet famine food. cooked in three waters
Tagaya	Melon seeds taken from excreta of cow.	Wash, pound, add tabakaten	Sweet "like dates"
Alikid	Fruit of melon after wet season; found "everywhere"	1. Put fire in hole in sand, remove, add melon 2. Boil in water	Food source, water source (juice), medicine
Ibellawent	At end of hot season, on dunes.	Eat raw	A sweet

Abadebit	--	Fruit: raw Grain: pounded Leaves: boiled	--
Tamasalt	Grain found in ant hills or beaten out of husk with stick	Grain: pound, boil, mix with ishiban Leaves: cook in water.	Food source
Fruit:			
Amalaja	Shake from trees at end of dry season	Pound, sieve, add sour milk and ibakaten	"Very good for getting fat"; enjoyed by sheep
Tamint	Fruit of tadant	Dry near fire, pound,put in cloth in water 10 days; cook with meat; also can be eaten raw	Food source; a sweet
Ebelekunt	Fruit of agar, when ripe are black	Eaten fresh; dry, then add water	Sweet, good for journeys
Aboragen	Fruit of abora gathered from ground during dry season	Eat fresh or cook green fruit	A favorite sweet of children; nut is important medicine
Tamont	Picked from bush in wet season	Eaten raw, skin is discarded, nut is sucked	Only eaten by children

		sucked	
Tarakot		Ground, seeds discarded, or eaten as is	For sweetening sour milk
Tabakot	Picked by iklan	Eaten as is or ground, mixed with water, baked	The most important fruit for sweetening
Gums:			
Awarwar		Eaten raw	Anti-sorcery
Tamat		Eaten raw	Tonic
Afaja		Eaten raw	Sweet
Ibalugalug		Sucked	Medicine for mouth sores

TABLE 3-7 Commonly Used Vegetables, Fruit, and Gums

Meat of domesticated animals is used mainly on special occasions such as religious festivals, the arrival of visitors, or major camp movements, and for medicinal purposes, although Kel Tamasheq believe that meat should be eaten at least every week in order to maintain health. They have been known to stage a "special occasion" to justify butchering an animal. Goats are most frequently used because they are least valuable and are generally kept near the camp. A larger animal may be butchered when meat is scarce, if there are many visitors, or if it is too weak (from thirst, hunger, or travel), old, or sick to continue. However, the latter depends on the type of infirmity; victims of contagious bovine pleuropneumonia, for example, are not eaten.

Wild animals are seldom eaten; this may be partly because of their current scarcity, food taboos, or possibly the lack of means or expertise in hunting. (Weapons consist only of knives and throwing spears; no bows are used except as toys.)

Animals are killed by slitting the throat. Blood and stomach contents are the only parts not used, and the meat is divided according to strict social rules: the chest to marabouts, if present; the ribs to the man of highest rank; the head to the shepherd or owner of the herd; the neck to elders in the shepherd's family (if he is young); the stomach and intestines to the iklan; the lower legs to children; and the rest to the owner of the animal. This pattern differs slightly according to the type of animal. Large animals such as camels or cows must be partitioned among the whole camp; sheep and goats are primarily for the family that butchered them, although almost anyone may come to eat with that family or ask for some of the meat. Organ meats (liver, heart) are roasted on hot coals immediately after butchering and are eaten with salt by the head of the family and respected guests. Later, the haunch and meaty portions are prepared in any of the following three ways: (1) roasted by being buried in the sand with a fire built on top; (2) boiled in water with the meat then removed from the bones and pounded in a mortar to break up the fibres, then served with grain, or very rarely, with butter only; (3) cut from the bones, then divided into thin pieces and hung inside the tent to dry. Bones are discarded.

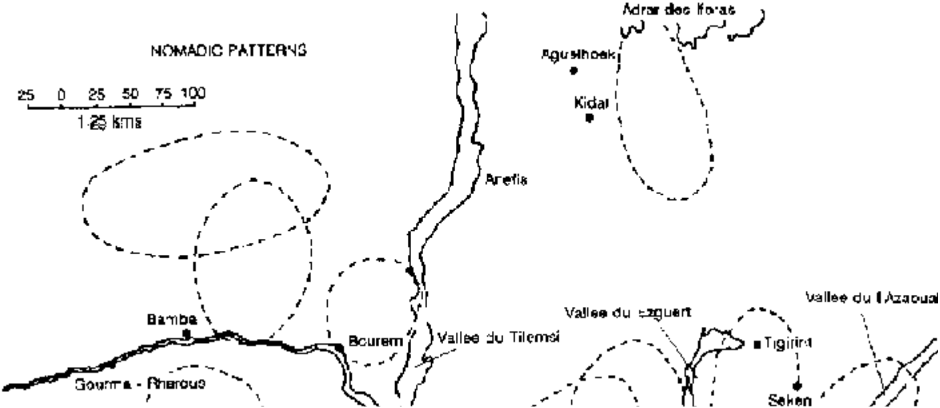
Fresh milk is the first meal of the day for children and is taken at dawn; the adults drink only sweet tea and chew tobacco. At midmorning, "crme" is eaten by men and children, and less frequently by women. In early afternoon, a major meal of grain with either meat, butter, or milk is prepared, if grain is available. In the evening, fresh milk is drunk by all, occasionally supplemented by a small dish of grain if milk is scarce. Visitors are usually given a meal of meat and grain, preferably millet or rice, in the evening.

Food is served in wooden bowls with four or five people partaking from each, using either the hand or a wooden spoon. Bones are broken open with knives or "Neolithic" stone implements to obtain the marrow; the bones are then thrown outside the tent. If the camp remains in one place for more than a few days, such debris will be swept further away from the tent (8 to 10 m). Occasionally, dogs (one or two of which are present in most camps) will scatter bones further. However, scavenging is not their main means of obtaining food, since they are fed on milk and grain when it is available. Bones seem to accumulate on the west side of the tent during the cold season and on the east side during the hot months. (At other times, camps are not stationary long enough for debris to concentrate.) This difference may be due to the fact that in winter meat is eaten to celebrate the arrival of visitors and is served with the evening meal when people sit on the west side (perhaps for protection against easterly winds). During the hot season, however, meat is most frequently eaten at the main afternoon meal when tent occupants gather on the shady east side. Meat has less of a ceremonial function at this time, since visitors are not common; it is more important as a food source because milk and grain are insufficient and also because many animals die of starvation or thirst during the hot season and must be slaughtered.

Determinants of Movement

The nomads' most common response to pressures from the physical and social environment (hunger, thirst, political hostility) is to move. It is one of the most effective means of exploiting widely scattered and scarce resources. The precise nature of the movement (its time, frequency, direction, and distance) is the result of a complex interplay between the needs of people and animals and the availability of food and water, the latter being the most critical commodity.

Kel Tamasheq do not wander randomly, but circulate within general "home" regions, and within these regions, follow a habitual route, for example, south to north to south again, although both the region and the route can change in response to unusual political or seasonal situations. The nomadic pattern is oriented toward seasonal water points and key pasture areas (figure 3-1).



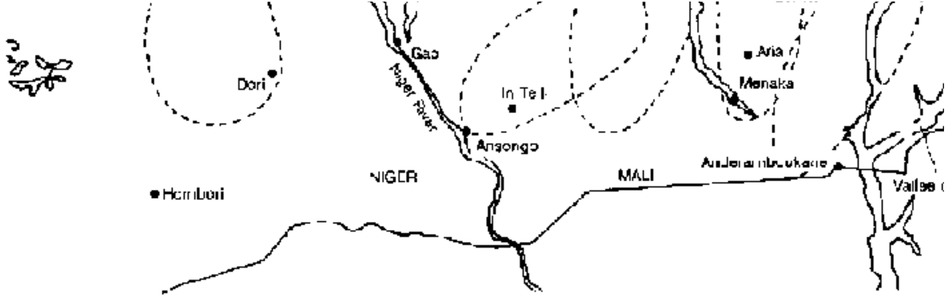


FIGURE 3-1 Approximate extent of areas occupied by nomadic pastoral groups in the vicinity of the lower Tilemsi Valley, Mali.

Animal	Maximum Days Without Water* Cool Season	Hot Season	Maximum Days Without Food Hot Season	Maximum km/day
Camel	90	5-7	5-7	80
Cow	3	2	2	20
(Calves)	1	1		10
Goat	15	2	2	20
Sheep	30	1-2	2	30

*Depends on quality of pasture

TABLE 3-8 Resistance of Animals to Thirst, Hunger, and Fatigue

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Animal	Maximum Days Cool Season	Without Water* Hot Season	Maximum Days Without Food Hot Season	Maximum km/day
Camel	90	5-7	5-7	80
Cow	3	2	2	20

(Calves)	1	1		10
Goat	15	2	2	20
Sheep	30	1-2	2	30

*Depends on quality of pasture.

In the first months after the rains, from September to December, water is obtained from shallow, handdug wells that are usually surrounded by adequate pasture. Camps are located near the water, and this enables the group to remain in place for as much as a month at a time. As this water dries up, usually between January and February, groups move toward more permanent sources, such as bore-holes or the traditional hand-dug wells in beds of now-dry lakes. As pasture is consumed in all directions around these wells, the camps move gradually outward, spending no more than a week in one spot, until the distance between water and pasture is the limit that mature cows and caprines can travel (table 3-8). At this point, occurring at the height of the dry season when it is tied to one water source, the camp is positioned between the well and the pasture and, again, remains immobile for several weeks. The exact placement of the camp itself at this and all other times is determined by the water requirements of the young animals that remain inside the camps, as well as by those of the people themselves. Lambs, kids, and humans do not require great quantities of water (sufficient amounts can be carried in leather water bags for two days' supply), but since calves drink more, they must be taken directly to the water source every day. The extent of their daily travel depends on age and physical condition, but is unlikely to exceed 10 km each way. It can be postulated, then, that it is the calves that determine the exact distance of the camp from water.

On the other hand, the crucial decision of when to move appears to depend on the food needs of mature animals, specifically those that are lactating. They must return to the camp each evening to be milked and to feed their young, and therefore cannot travel more than 20 km (for cows) in search of pasture. To ensure their return, herders send the mothers in one direction and their young in another, on the theory that in the evening both will converge on the camp - the young being hungry and the females seeking relief; if, however, the two somehow meet while grazing (a not uncommon occurrence), neither comes back to camp. When the pasture is consumed beyond this limit, the camp and herds must move to another permanent water source or possibly, if it is near the usual end of the dry season or if the source is beyond the capabilities of the animals to walk, the group may remain and try to eke out a living until the rains come. In either case, and especially when the rains are delayed, a considerable toll is taken in animals.

Such extreme conditions do not occur every year, but they serve to illustrate the critical balance that exists between man and land at all times in a marginal environment. Nomadic life requires a sensitive evaluation of the needs of animals and an awareness of where the optimum supply of water and pasture can be found. Increase in population or change in environmental conditions may bring nomads into competition for these limited resources. It seems likely that these mechanisms were at work 4,000 years ago when the prehistoric pastoralists were being forced out of the Sahara to find new and more permanent water sources.

During the wet season, an entirely different set of considerations dictates the location of camps and the time of movement. The needs of animals are no longer critical - new grass is growing and water is available everywhere in streams and shallow lakes. At this time, the mature nonlactating animals (which until now have been totally independent of the camps and wandering freely in search of food and water) are rounded up, a process that may take several weeks. When all the animals have eaten enough new grass to regain strength lost during the hot season, the camp and its consolidated herds embark on a month-long journey to areas of salt earth ("terre sale") which are generally located to the north on the edge of the Sahara (the precise area differs for each region). This trek serves both a health and a social function. In the first case, it allows the animals to graze on salt grasses and drink water of high mineral content, which the nomads believe is necessary for the health of both their animals and themselves. In the second, since related tribes usually frequent the same terre sale this is a time of feasting, competitive sports (camel racing, wrestling), and, above all, courtship.

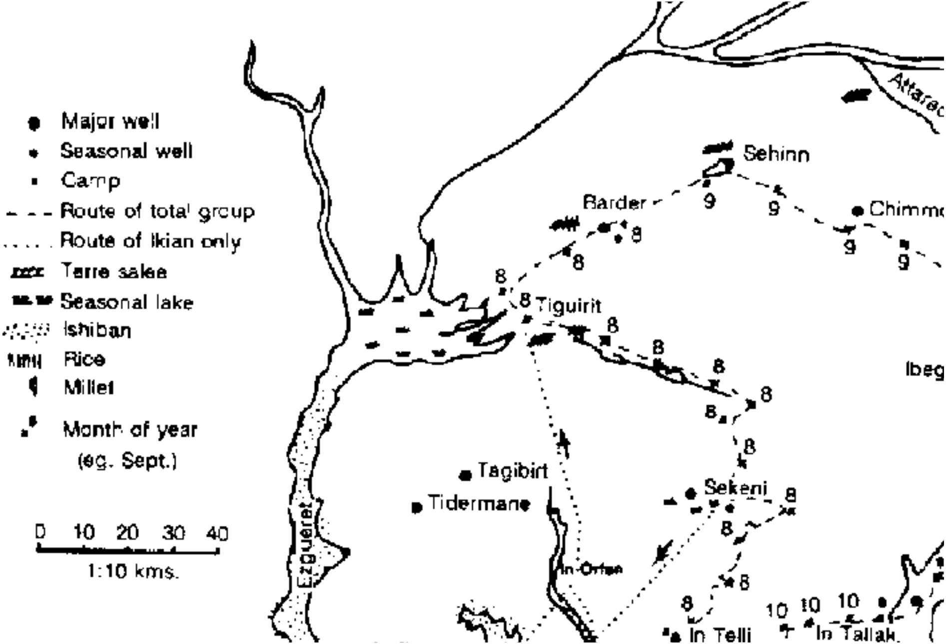
During the wet season, the camps usually move each day or every other day, although the exact speed and frequency of movement depends on the strength of the young animals that are usually being born at this time; for example, newly born camels must rest at least a day after birth before they can travel, and even then they may not be able to keep up with the herd; a herder will often drop back to walk with the mother and infant. Progress is often slowed also by the need to retrieve the animals that have wandered during the previous night (during seasons when movement is infrequent, the trek animals are collected and hobbled the day before, but when camp is being moved each day, the animals must be left free to graze at night). A minor factor affecting the speed with which the salt areas are attained is the search for appropriate routes. Large lakes must be skirted, and in the Sahara region good water and pasture again become a problem. The northward journey, then, is not direct but carried out in a zigzag fashion (figure 3-2).

During all seasons, the distance that a camp moves at any one time strictly depends on the availability of water and pasture, but it normally ranges between 2 km and 30 km. Movement begins at dawn (it takes approximately half an hour to break camp) and continues only until noon. If still more territory needs to be covered, the journey will resume after the day's heat diminishes.

During August and September, the movement pattern of iklan both those who are a component of other camps and those who are independent, is slightly different from that of the nobles and marabouts, since it is influenced by their search for wild grains. At the time of the first harvest, iklan groups will converge upon the areas that have been favored by rain or soil conditions. If the yield is abundant, the second and third harvests will be limited to the collection of grains encountered while herding; movements will be less affected by the need to harvest.

A local variation of the general pattern of movement is found among groups living near the Niger River, especially those between Timbuktu and Gao. At the end of the hot season, and especially if it is prolonged or severe, the groups will reverse their pattern of following the diminishing pasture away from the river and make a forced march back toward it through now barren country in order to feed their animals on the plant species, such as Echinochloa stagnina (burgu), exposed by the lowered water levels.

Movement of all groups is influenced by death and disease. Nomads are aware of the danger of contagion and will isolate the tent of one who has an infectious illness. When traveling, they will try to pass on the upwind side of a stricken camp. When a person dies, he is buried several hundred meters from the camp, oriented to the east in the Muslim fashion, and the grave is covered with straw, after which, ideally, the camp will be moved. Kel Tamasheq do not condone amputation, surgery, or mutilation of the body, even in order to save life.


Major well
Seasonal well
Camp
Route of total group
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Terre salee
Seasonal lake
Ishiban
Rice
Millet
Month of year
(eg. Sept.)
0 10 20 30 40
1:10 kms.
Sehinn
Barder
Chimm
Tiguirit
Ibeg
Tagibirt
Tidermane
Sekeni
Ezgueret
In Ortsa
In Telli
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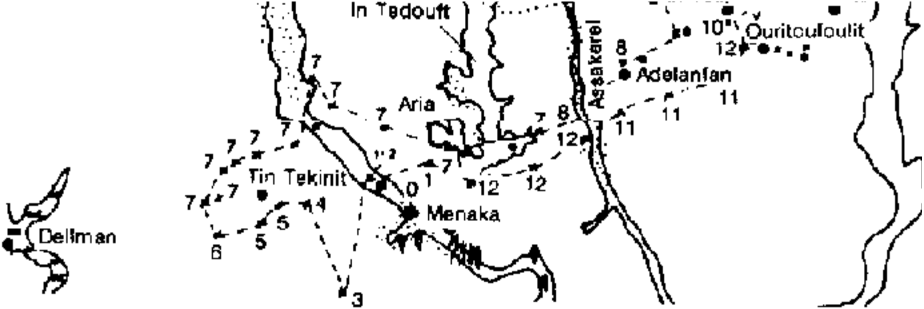


FIGURE 3-2 Seasonal pattern of movement by one nomadic group in southern Mali.

Camp organization

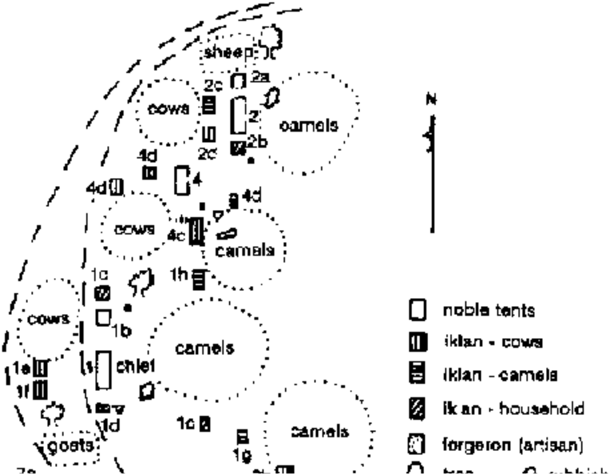
The necessity for more or less constant movement has greatly influenced both the material culture and the living pattern of the Kel Tamasheq. The former is restricted to household necessities that are light and not easily broken; for this reason, little pottery is used; most vessels are made of wood. The only item of pottery noted in one of the camps was a large broken pot (1 m diameter) in which hides were soaked to remove the hair before tanning. With superfluous items cut to a minimum, aesthetics are expressed in such functional items as carved tent poles, beds, bowls, and intricately woven mats, as well as through personal decoration - hair styles, necklaces, swords, charms, and leather wallets.

Tents are the logical response to needs for a shelter that can be quickly and easily dismantled and rebuilt during seasons of rapid movement (figure 3-3). Tents are placed over a framework of wooden poles; these poles are lashed together with ropes made from the bark of Acacia tortilis (afagag). They are fashioned from goat or cow hides, the number depending on the wealth or social status of the occupant - from as few as 4 to as many as 60 - sewn together with thongs. They constitute the heaviest and bulkiest item of the Kel Tamasheq's gear, but this weight is necessary: the tents must withstand the high winds and torrential rains of the wet season. During these storms, the nomads secure the tents by tying their edges to the bases of the auxiliary tent supports and by throwing across the tent ropes, whose ends are knotted around straw and buried in holes 1 m deep. Tents have an average life of 10 years and are easily repaired by stitching circular patches of leather over rips or holes. During the hot season, when the camps are stationary for weeks at a time, straw huts are constructed that are cooler than the dark tents; the latter are stretched out on the ground where they are mended and butter is melted into the leather by the hot sun to soften and preserve the skin. Red ochre (temesgeit) is then rubbed in as an additional preservative.

Camps are located in relation to natural features according to the season. In the cooler months (September-November and February March), the camp is placed near areas of small trees or bushes that can provide fodder for young goats. In the cold months of December and January, the camp is moved into the shadow of an acacia "forest," or, if that is unavailable, near a large dune to gain protection from the cold winds. During the hot and rainy seasons, the camps are made on top of high dunes to take advantage of cooling breezes during the hot season and to avoid the mosquitoes and water runoff associated with the rainy season.

The nomads explain that at no time are camps placed within 100 m of a water source, since it is prohibited to eat in such places.

Within the camps, there appears to be no pattern regarding the placement of tents other than personal preference (some family heads prefer higher ground, others like to camp beside a tree, and some families habitually camp near each other because they get along well or have herds in common). The exceptions are that tents of slaves who care primarily for camels (iklan n iminas) will be placed to the east of the master's tent and the tents of those who are "slaves of the cows" (iklan n fess) are always to the west. Tents of the artisans are generally situated in a cluster to the west of the camp. The chief or most respected person chooses his place first and the others follow, apparently in order of seniority. Tents appear to be always oriented toward the east, which is contrary to the observations of others: (Briggs, 1960) in the northern Sahara, and Nicolaisen (1963) among the Kel Ayr. Baggage is piled on the north and south sides allowing the east and west sides to be opened when sunlight, and sometimes wind, is not coming from these directions (at noon, tents are opened on both sides to give maximum shade and ventilation).



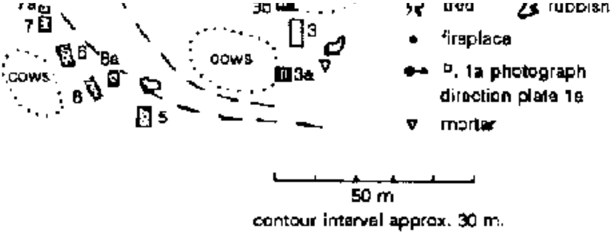
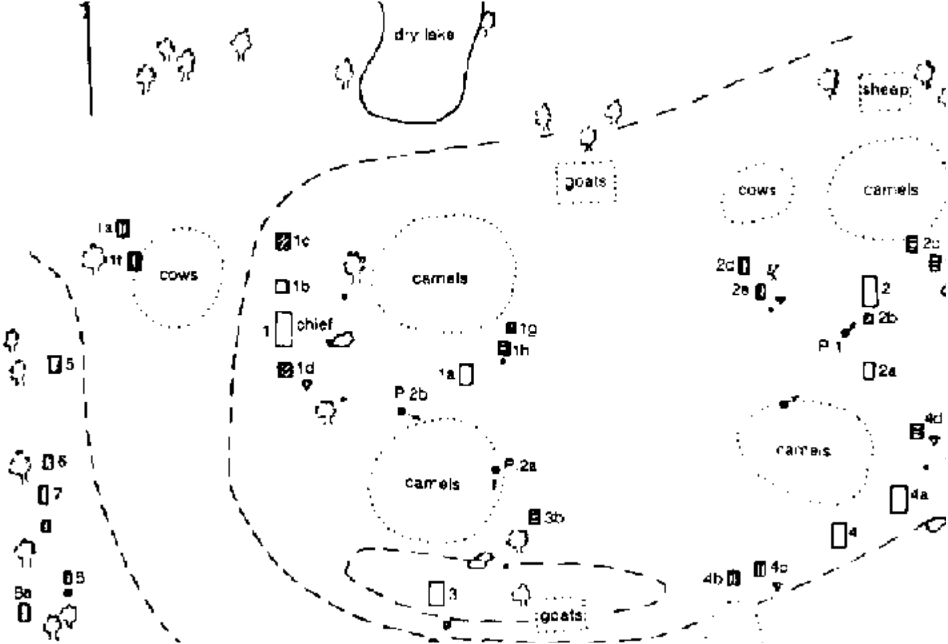


FIGURE 3-4 Typical pastoral nomad's camp on a sand dune during the wet season.

The distance between tents varies according to the terrain. On small dune tops, the major family tents of nobles, for example, may be as close as 10 m to each other, with the household slave tents clustered within 2 m (figure 3-4), whereas on open plains they may be separated by 40 m, (figure 3-5) obliging the women to ride donkeys when visiting friends on the opposite side of the camp.


dry lake
sheep
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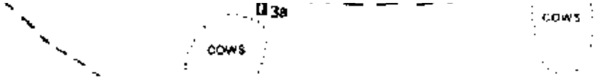

FIGURE 3-5 Typical pastoral nomad's camp on the open plateau during the hot season.

Camps as a whole are vaguely crescent- or U-shaped. At night when the animals return to the camp for milking, the camels are placed on the inside, and goats, sheep, and cattle lie outside. There is no rigid rule concerning this and it is largely a matter of what is most convenient for those who care for them. Newborn sheep and goats are kept inside the tents. Older ones are allowed to run free in the camp during the day but are tied by their necks to a rope stretched between two stakes at night. Bush enclosures are sometimes made to protect goats and sheep from jackals. Newborn camels are tied by one foreleg to individual stakes in the middle of the camel yard; when older ones come back from pasture they are tethered in a group to one stake. Calves are tied individually by the neck at night and are sent to pasture during the day. Donkeys'front feet are hobbled when they are likely to be needed, but otherwise they are allowed to roam freely. It must be emphasized that it is only young animals and mature lactating females that are usually found in the camps; the others are brought in only when camp is about to be moved and even then not all are found.

Since material culture is limited among the nomads, abandoned cool-season campsites are indicated only by trampled earth, dung, lack of grass in the surrounding area, and a few wooden branches used as auxiliary tent supports. Hot-weather sites may show traces of straw huts, and rainy season camps often have remains of "nests" that children build in trees to escape the mosquitoes, or occasionally, bed supports that lift sleeping mats 1-1.5 m off the ground for the same purpose. There are sometimes remnants of charred branches left from the huge bonfires that are built during wet-season storms to keep goats from stampeding. In the section of the camp inhabited by artisans, small pieces of brass and iron staples used for mending chips and cracks in wooden bowls may be found. Also, there are discarded pods of Acacia nilotica (tagart) that have been used for tanning hides, as well as numerous strips of leather and pieces of matter. Nearby trees may have scars where strips of bark have been removed for use in medicines, tanning, and rope making, depending on the type of tree. In noble camps, the pounding and winnowing of grains is done by (iklan beside their tents; therefore, seeds and chaff may remain in these areas. Cooking fires are usually built near the tents of the household (iklan whereas fires for warmth, used only during the cold months, are located directly in front of the imajaren tents. No stones are placed around campfires, and such places are indicated only by darkened sand, charcoal, and ashes (however, this could be because of the scarcity of rocks in the areas observed). The precise location of tents is indicated by areas swept free of dung and straw. The debris from the tents (such as cooked grains, seeds of tarakot, excrete of babies, camel dung and wood fragments used for games, and pieces of charcoal used for heating tea) are accumulated about 10 m to the east or west of the tent site, where the bones have also been thrown.

The population density is approximately 0.3 individuals per square kilometer. The size of the camps depends primarily on the social class of the members, since a camp of noble Kel Tamasheq would include their slaves and artisans as well as their own families. Secondly, size depends on the availability of pasture; a large camp may split if there is insufficient food for the animals. Some nomads maintain that in the past, camps were considerably larger, perhaps consisting of several hundred people, because pasture was more plentiful. Others insist that this only appears to be the case because either the individual camps of 100 were more common, as slaves who now travel independently formerly lived with their masters, or these small camps would migrate as a group for protection against enemies rather than in dispersed units as they now do.

An example of the layout and demographic composition of a large Kel Tamasheq camp (Oulliminden) is presented in figures 3-4 and 3-5 and table 3-9 respectively. The sexual distribution varies with the season, since during the months of February to May and September to November the males often make journeys to sell animals and buy necessities, collect taxes and tribute, conduct raids on enemies, or just visit. Recent major epidemics of smallpox, measles, pneumonia, and meningitis have decimated the youngest and oldest age groups. (In the past, war appears to have been a more significant factor in mortality than was disease.) A few small groups differ significantly from this model, for their social codes have inhibited marriage and, consequently, they are suffering major population declines.

Herd size reflects the wealth of the owner but not his social status, since, at present, there are slaves and vassals who have more animals than do the nobles. Traditionally, however, the noble was considered to own the animals of his slaves and to have access to those of his vassals. The number of (iklan tents associated with an imajaren, vassal, or marabout tent is, on the other hand, an indicator of status. For example, the largest herds among the Kel Tamasheq are owned by the vassal tribe, Deousahak, but they do not have iklan and care for the animals themselves.

Conclusion

This description of the habitation and exploitation pattern of a nomadic pastoralist group in a marginal environment with relatively harsh climate and scarce resources is suggested as a possible analogy with post-Palaeolithic herding peoples who inhabited the Saharan and Sahel zones cat 4000-1300 B.C. This pattern utilizes almost all of the resources of the environment, either directly or through the medium of animals, and obtains them in sufficient quantities to sustain life by movement from area to area.

In terms of non-food resources, wood is the major element drawn directly from the environment. It provides heat for cooking, and is used for making tent supports, beds, vessels, and eating utensils.

Tent	Social Category	Total Persons Per Tent	Adults M	Adults F	Children Living	Children Dead	Else-where	Others Iklan	Others Artisan
1	Imajaren	7	1	1	3	2	3	1	1
1-a	Imajaren	3	1	1	0	0	0	1	0
1-b	Imajaren	[illegible]	[illegible]	0	0	0	0	1	0

1-b	Imajaren	3	2	0	0	0	0	1	0
1-c	Iklan-tent	3	0	1	2	1	1	0	0
1-d	Iklan-tent	4	1	1	2	0	0	0	0
1-e	Iklan-cows	7	1	1	5	3	1	0	0
1-f	Iklan-cows	8	1	1	6	1	0		
1-g	Iklan-camel	4	1	1	2	0	1		
1-h	Iklan-camel	8	1	1	6	0	0		
2	Imajaren	5	1	1	3	1	0		
2-a	Imajaren	2	1	1	0	0	0		
2-b	Iklan-tent	2	0	1	1	0	0		
2-c	Iklan-camel	4	1	1	2	2	3		
2-d	Iklan-cow	2	1	1	0	0	0		
2-e	Iklan-cow	5	0	1	4	1	2		
3	Imajaren	5	4	1	0	0	0		
3-a	Iklan-cows	6	1	1	4	2	0		
3-b	Iklan-cows	4	1	1	2	0	1		
4	Imajaren	6	1	1	4	2	0		
4-a	Imajaren	4	1	1	2	1	0		
4-b	Iklan-cow	5	1	1	3	3	0		
4-c	Iklan-cow	6	1	1	4	5	0		
4-d	Iklan-camel	5	1	1	3	3	0		
5	Artisans	9	1	1	7	0	0		
6	Artisans	4	1	1	2	2	2		
7	Artisans	5	1	1	3	2	0		
7-a	Artisans	1	0	1	0	0	1		
8	Artisans	5	1	1	3	2	0		
8-a	Artisans	2	0	2	0	0	0		

TABLE 3-9 Demographic Composition of a Tamasheq Camp (June 1972)

Animal	Transport	Meat	Milk and Products	Hides	Social Function	Occasion When Sold
Camel	a) Tent, large utensils b) Men, small boys, traditionally women also c) Grain in leather sacks d) Salt slabs e) War drum	Rarely sick or weak animal	Fresh milk	Camel whips	a) Prestige (from number and form of animals) b) Bridewealth c) Camel dance for celebration and healing	Dire need tax, fines
Cattle*		a) For large groups b) Weak animal	Sour milk Butter Cheese	Tents Sandals	Indication of wealth	Large purchases: tax grain, clothes, saddles
Sheep		a) Religious sacrifice b) Visitors c) Celebration	Fresh and sour milk Butter	Pouches Wallets (hair not used)		Small purchases: grain, butter, leather work
Goats		a) For visitor b) Hunger	Fresh milk Cheese Medicine	Water bags Milk churns Cushions		Smaller purchases: tea, sugar, tobacco, salt
Donkeys	a) Women and children b) Pots, tent poles,		Medicine			

	and small camp gear c) Water			
Horses	a) Respected elders		Chiefly status	
Dogs		?	Guarding camp and herds, for hunting, as pets	Usually given as gift

*Apparently bovids are used for transport in the northern Sahara, but this was not observed in the Sahel.

Table 3-10 Comparison of uses of various domestic animals

The food resources directly available are vegetables, fruits, birds, fish, and wild grains. Food taboos restrict the use of a number of these items, especially among the noble classes, but wild grains are an important source of seasonal food for all. The primary subsistence sources, however, are the domesticated anneals. They supply food and are the means for acquisition, through trade, of other goods, such as clothing, knives, and domesticated grain; they provide many of the raw materials necessary for nomadic life-hides for tents, sandals, and saddles, and urine and excrete for medicines; they are the means of transporting both people and camp gear (table 3-10). The animals, thus, are the primary link between the Kel Tamasheq and their environment, the West African Sahel, and their welfare largely determines the welfare of the people.

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Dromedary pastoralism in Africa and Arabia

GUDRUN DAHL AND ANDERS HJORT

Introduction

This paper provides an overview of different economic systems in which the breeding and ownership of camels play a significant role; it explores some of the strengths and weaknesses of such systems.

The emphasis is on camel pastoralism in Africa and Arabia. ("Camel" here refers to the dromedary.)

While a number of anthropological efforts are focused on more general studies of cattle pastoralism, few efforts have been made within the equivalent field of camel pastoralism. One exception is Rubel (1969), who has tried to create a "generative model" for residential and kinship patterns, comparing a number of pastoral societies with varying emphasis on camels or small livestock. Her hypothesis is that small-stock pastoralism necessitates a wider range of pasture and water than camel pastoralism, and that this need for resources in turn affects the social structure of the herders' groups: the strict ideal of patrilinearity must be compromised in practice so the small-stock herder can maintain a widespread network of alliances also outside his patrikin, ensuring access to such resources. Rubel has been criticized (Pastner, 1971) for using untrustworthy data and for relying too heavily on simplistic assumptions about the hardiness of camels. One of her critics, Lewis (1975; 1977), however, notes the correlation between cultural differences and variations in "species emphasis" among neighboring pastoral peoples in northern Kenya and suggests that different combinations of livestock could indeed provide a generative model for predicting forms of social organization.

Our focus is on systems of production rather than on particular groups of people or their cultural traits, and we are concerned both with constraints that may be caused by ecology and an economic dependence on camel herds, and with restrictions on production caused by the social organization.

Reproduction and risk

Camel keeping is fundamentally a high-risk undertaking (Sweet, 1965), due to the animals' very slow reproduction rate. Only when she is about six years old does the camel dam start to bear calves, and then normally only one calf every second year. In contrast, the cow first calves at about three or four years of age, and then every year thereafter. If a camel owner is struck by misfortune and left only with a minimal number of camels or none at all, rebuilding the herd is a very slow process. Breeding animals are very expensive to buy, and owners are often reluctant to part with them. Lost camels, in many cases, are never replaced; the loss is as final as when a farmer or peasant becomes landless. A dramatic example is the fate of the Sakuye Borana in northern Kenya, who lost virtually all their camels during a war in the early 1970s. Practically all the Sakuye were pushed out of their traditional livelihood, because they were unable to provide proper care for the remaining animals and were incapable of expanding their holdings fast enough to reenter viable pastoralism. They were forced to leave their area to seek other income and thereby lost effective control over their pastures, which were subsequently used by other camel herders. It is now almost impossible for even rich Sakuye to purchase breeding animals in the market (Dahl and Hjort, 1979).

The hazards of camel reproduction have also been used as an explanatory variable by authors (notably Sweet, 1965) who have sought to understand the institutionalization of raiding in Arabian camel-owning societies. By acquiring animals in a raid, the herd owner can preclude several unproductive years in the development of his herd. One partial solution to the risk is that many camel-owning societies in Africa and Arabia have systems of property holding that redistribute the risks among herd owners. All the animals of a particular patrilineal kinship group are in some sense regarded as common property and are marked with one single brand. Each individual herd owner, however, can dispose of his stock as he pleases, as long as he fulfills his duties to take part in lineage redistribution of stock to those stricken by misfortune. Such redistributions may be organized by a council consisting of all mature herd owners in the lineage, or by specially appointed elders or tribal chiefs (Dahl, 1979). Among the Sakuye, the lineage members were responsible for helping each other to retrieve lost stock and to make a collection of a nucleus herd for any member who had lost his camels through misfortune; this was on the condition, however, that he was not known to have spent capital (female breeding stock) carelessly (for example, by selling it). (Due to the high risks associated with herd regeneration, the camel husbandman must show respect for capital expenditure: the cultural system often stresses this by various semi-ritual taboos against sales.) When a majority of the camels of the Sakuye people had been lost, such countermeasures as lineage redistribution were of course ineffective.

Forms of lineage redistribution may be supplemented with systems of mutual loans of camels; in practice, then, the herd that is managed by one household belongs to many owners. Such a system of chains of loans has been described by Spencer (1973) for the Sakuye's neighbors, the Rendille.

Management and labor

It is not only the pattern of herd reproduction that is significantly different for camels and cattle. Camels are able to move quickly and to reach distant pastures. Such movements are necessary to achieve a varied diet. In comparison with cattle, camels require frequent "salt cures" at licks or on pasture on salty soils unless there is access to water with appropriate mineral content. Mobility is also needed to avoid hygienic problems and tick infestation. Camel calves are highly vulnerable to ticks, and as a countermeasure the pastoral camp should not remain more than 10 days at the same place. Camel oriented societies differ in the degree that the main body of household members follows the camel herd in all its moves; but when they do, much energy is spent on the frequent erection and dismantling of tents. Camp moves are usually more frequent than among cattle herders.

Neither mating nor birth can be left to the camels themselves: the attention of experienced herdsmen is necessary. Camels, especially dams about to calve, have a tendency to stray, and tracking them involves much work.

Although camels frequently go for long periods without water, they drink a great deal whenever they can. In the dry seasons, it can be quite a task to draw 90 liters of water per animal from a deep well. Watering at ponds or reservoirs, which is easy with cattle, requires great attention with camels, especially at places where livestock of other species are watered as well. Camels tend to get into the water and foul it and animals of other species refuse to drink it.

Camel pastoralism can generally be said to be more troublesome and demanding than cattle pastoralism, though there are seasonal changes to the pattern. Two slightly different examples can be mentioned, one from southern Arabia and the other from Kenya.

Among the Al-Murrah of Rub' al-Khali, the members of a particular patrilineal group tend to congregate around its oasis or permanent well during the hot season. There is not much herding to be done, as the vegetation is restricted to narrow and isolated patches and the camels do not stray far from the watering places. By contrast, the cool season is a period when much time has to be spent in aiding mating and calving and in tracking wandering camels (Cole, 1975). It is a time of plenty of milk and easy access to water and pastures. Families gather together and meet other patrilineal groups. There is much interclan feasting.

In northern Kenya, the rainy season similarly involves both work linked to camel reproduction and to congregation and enjoyment. Since resources are abundant, but also because the areas open to camels become restricted, herds and people are concentrated in areas with good drainage. Families that tend to be parceled out into many small sub-units during the dry season are able to stay together in the rainy season. As drought proceeds, the main camps must live closer to the permanent waters, but the camel herds and their herdsmen roam widely in search of pasture. "Almost every able-bodied person, including children from the age of seven, is pressed into service...." (Tarry, 1978). Wet season routines sometimes demand a very intensive input of labor by a restricted number of people. Dry season routines, on the other hand, put a strain on the number of people available because there is a proliferation of tasks.

One way of countering the high risk of camel pastoralism is to combine camel rearing with the rearing of sheep and goats that reproduce quickly and so provide a viable pastoralism and a hedge against misfortune, but this also implies serious constraints on manpower. For example, Torry (1977) indicates that for the Gabbra in northern Kenya, the labor-intensive nature of multispecies stock management denies able-bodied persons considerable freedom from productive work during certain periods, especially as compared with cattle pastoralism. The Gabbra normally keep different kinds of stock in their household property, and most Gabbra households are dependent on immigrant labor at critical seasons. Gabbra households in a camp also try to pool labor resources to care for the family herds through such periods.

Because each form of livestock has needs differing from those of other forms of livestock, the minimal number of herdsmen must be large in order to provide specialized care to each species.

Even a family that owns only camels must still give special attention to the several categories of camels. Among the Sakuye, for example, it is said that herd owners tried to mate all their dams with the same male and then to separate this group from contact with other males until it could be seen, after one to four months, whether the dams were pregnant, lest other rutting males cause miscarriages or injure the darns. The dams and their sire would be sent away, while the newborn calves and their mothers, which constituted another group demanding special attention, were kept close to the camp. This group was put under a rule of ritual seclusion and could only be herded and milked by chaste young herd boys. Among the Al-Murrah, Cole (1975) found that there was particular concern over a similar category of newborn camel calves and their mothers that had to be given water every week; these were kept separate from both the mobile milch camels and the pregnant dams, which were left unattended close to the camp.

Subsistence production

In spite of the fact that there are many monographs on groups concerned with camel herding, detailed production data are scanty. The main food product obtained from a camel herd is milk. The camel is in many ways a more reliable source of milk than the cow.

She produces milk in greater quantity. To mention but one example, a Sakuye camel dam in northern Kenya can be expected to give about 4 kg daily as compared with 0.5-1.5 kg for a cow in the same area. At the peak of lactation, the daily yield can be as much as 12 kg. Knoess (1976) found average daily milk yields of between 2 and 8.4 kg in Afar camels in Ethiopia. The lactation period may last for 18 months: up to a year is considered normal under traditional pastoral management. This means that the owner of a number of camels can have safe access to milk throughout the year.

In areas with only one rainy season, a majority of the camels are sometimes at the end of their lactation just before the onset of the rains, and the end of the dry season may involve a critical period of food shortage for the pastoralist if he has no access to grain or other products that are unrelated to camel rearing. It is interesting to note that one of the few areas where there are almost totally subsistence-oriented camel pastoralists is in northern Kenya, which has an expected pattern of two rains per year. There, sections of the Rendille and Gabbra live almost exclusively on the products of their camels and small stock.

There are, however, some impediments to milk production even in that region. If one or two consecutive rains fail, there may be a delay in camel reproduction - and hence in lactation - which is more serious than such delays would be in cattle rearing or small stock pastoralism. A camel may go one or even two years without beginning a new lactation. Moreover, there is a risk that all the camels go in milk simultaneously, which gives one year of abundance at the cost of the next year's milk supply.

Milch goats and sheep for slaughter ensure a more reliable supply of food. Goats come into milk quickly after the onset of rains. This is one of the reasons that camel rearing is frequently combined with the husbandry of small stock.

Subsistence pastoralists rarely slaughter camels for meat. Slaughter is reserved for ritual occasions or when there are other large gatherings or when the camel is old or weak, and even then it depends upon the value of females for reproduction and of males for a wide range of alternative uses. To slaughter a camel is a major decision, but the gap left when a goat or sheep is killed is quickly filled: the meat of the smaller animal can also easily be consumed by the family without involving any larger group in communal sharing.

In northern Kenya, camels are occasionally bled to provide for particular human demands of iron, salt, and other nutrients. The use of camel blood as human food seems to be restricted to those Nilotic peoples who have acquired camels (notably the Turkana), to camel-owning Borana groups, and to the most western Somali. It is not acceptable to orthodox Muslims.

Apart from the production of milk, meat, and blood, camels supply skins and, theoretically at least, wool. Knoess (1976), who suggests that Afar pastoralists be made to sell camel wool, notes that its use is unknown in Ethiopia, and the same is true for the rest of the

Horn of Africa. Skins are used by pastoralists for household utensils, whips, and sandals (which are sometimes exported).

Marketing

The only area in the world where camel pastoralism seems to be predominantly subsistence-oriented is northern Kenya. Even there, camel pastoralists rely to some extent on neighbors practicing hunting or alternate forms of pastoralism. Most other camel pastoralists depend on exchanging some form of goods or services with their neighbors to obtain supplementary foodstuff from them. In such societies, camel milk continues to be an important food, but the diet is not exclusively built on it. Although it has a pleasant taste, it is not always acceptable to the consumer, and it has little or no market outside the community of current or former camel herders. (Dahl and Hjort, 1979)

It is difficult to ascertain the extent to which camel pastoralists in Africa and Arabia have traditionally been oriented towards a meat market. Because of the long intervals between camel births, it is difficult to regard any camel production as primarily meant to supply meat for the market. Bulliet (1975) mentions brisk markets for camel meat in Libya and Morocco, and in the 1960s, when Asad made his study of the Kababish of Sudan, the latter were engaged in the export of camels to the Egyptian beef market, despite serious legal restrictions, (Asad, 1970).

In 1970, Ibrahim and Cole (1978) noted that hardly any camels were sold by the Al-Murrah Bedouin; the camel meat in urban markets came from aged animals. By 1978, however, a majority of the Al-Murrah the authors interviewed had been involved in such sales.

In northern Kenya, prices rose considerably both for male and female camels during the 1970s, a fact that is usually explained by increased Saudi Arabian demand. Swift (1979) also reports a recent increase in the Somali camel export, not the least of which goes to Saudi Arabia. However, it is not altogether clear that this is owing to an increased demand for camel meat. Cole (1975) states that although camel meat is no longer as popular as it once was, there is now a great demand for pure-bred milk and riding camels among the Saudi Arabian elite, and markets are expanding. Schmidt-Nielsen (1964) suggests that the camel offers a most obvious solution to increased meat production in arid zones that have a low natural vegetation density that cannot easily be increased. However, despite the camel's superior adaptation to arid climates, the risks are great, the meat offtake fairly low, and labor costs high. In the case of Somalia, one report indicates an annual off take of 5 percent including both domestic meat consumption and export (United States Agency for International Development, 1979).

Any demand for camel flesh has so far had to compete with the demand for transport animals. The fact that the caravan camel has had great historical significance for North Africa and the Near East is well recognized. It was accentuated by Bulliet (1975) in a volume that presents an original discussion of how the domestication of the camel and the invention of the camel saddle 2,100 to 2,500 years ago brought a revolutionary change to transportation techniques and hence transformed the economic, political, and social history of the Near East. Transportation became less costly by camel caravans than by the wagons that had been used before, and militant camel nomads offered their protection and took over the trade.

Today, in the context of long-distance trade, the camel as a pack animal has been replaced by motorized transport, but its use as a work animal is still significant among many Arabian and Saharan people who do not necessarily breed camels themselves. The use of camels for plowing is common in many farming communities, for example by Bedouin cultivators in North Africa and by farmers in Yemen. Access to good transport animals is also crucial to people who pursue other forms of pastoral nomadism than that built upon camel rearing. For example, in the Isiolo District in Kenya, there used to be two groups of Borana pastoralists: one specialized in camel rearing and the other in cattle rearing. Until the camel economy broke down in the 1960s (due to a secessionist war in northern Kenya), the cattle-owning families used to have two or three camels each for transport purposes. This facilitated movements between different camp sites when pasture conditions necessitated such moves. Scarcity of transport animals has now slowed down their pastoral movements to the detriment of the proper care of cattle and small stock. Their transport camels formerly enabled them to camp at a distance from the rivers and wells, which was advantageous both for human and animal health and for the protection of pastures close to permanent waters. The camels could transport domestic water to the human household, or water and grass to animals that had to remain in the camp (young or sick animals), or could transport weak small stock or calves from one place to the other. Within the camel economy itself, there was of course also quite a demand for transport camels, reducing the proportion that could be exported.

Camels need close attention and constant movement if they are to reproduce well. The area where camels can reproduce is usually more restricted than the one where they can be put to work, and hence transport and work camels are more scattered than camel dams. The literature on camel economies frequently does not recognize this, and many sources state numbers of animals owned in terms of a sexually neutral category, which makes it difficult to judge the nature of the camel's economic role in the society concerned.

The number of people actually specializing in camel pastoralism is not very large, but a fairly large number depend on carrier camels. It may even be that it is in relatively short-distance transport for small pastoral producers and farmers that the camel had its most important role, rather than in the context of the caravan. There appears to be general agreement among writers on the subject that the demand for transport animals is decreasing, an opinion based on the observation of the changes in the structure of long-distance trade. More research is needed on these trends, and to ascertain as well whether there are changes in the demand for short-distance transport animals.

Predatory pastoralism

Having discussed the capacity of the camel for subsistence and commercial production, we should also consider a third historically important aspect, one that follows from the extreme mobility of the camel, namely its political role. The areas where we find camel pastoralists today are in the periphery of central states: areas where scarce resources make it uneconomical to try to maintain strict political control over people who tend to evade such control. Pastoralists can often react to political pressure by retreating into inaccessible regions. They are difficult to rule and historically have enjoyed military advantages through the agility of their animals.

There is a specific pattern of predatory camel pastoralism (Bouregeot, 1975) that is neither primarily subsistence-oriented nor that utilizes the camel as a means of direct production of marketable goods. The Kel Tamasheq (Tuareg) provide a good example of this.

In traditional Tamasheq society, camel ownership tended to be restricted to a hereditary caste of noblemen whose herds were tended by slaves. These slaves were of separate ethnic origin (Negroid), like the sharecropping vassals using land owned by the noblemen. Commoner Tamasheq specialized in religious services, in goat rearing, or oasis cultivation, and paid tribute in kind to the camel owners in return for protection. Bernus (1975) describes how, under the colonial pax, this service offered by the camel-owning noblemen lost its meaning and eroded, no longer giving rise to castes based on qualitative criteria of types of wealth but instead to more clear-cut quantitative inequalities. The Tamasheq noblemen were typical of a system in which camel-owning sections of diverse ethnic groups all over the Saharan area were able to maintain control over restricted patches of land of particular value - oases for cultivation, caravan centers, permanent well fields, and depressions with good grazing. Some of them, such as the Daza of Borku (Johnson, 1969), maintained outright ownership over oases or palm trees but did not themselves cultivate, leaving this to vassals or ex-slave groups, and returning only for the harvest. The

Daza and their northern neighbors in the Tibesti, the Teda, used to collect dates in early winter, and then use their nomadic camps as bases for caravans to other more sedentary people in order to exchange these goods for grain.

Systems of vassals and patrons are also found among the Bedouins of Libya and the Arabian desert area. In these areas, one can find dominant groups of noble, camel-owning Arabs who control land and are ascribed an elite status through reference to their places in tribal genealogies. In north Arabia, a system of ranked lineages is combined with a system of political control over vassal groups of smallstock shepherds, cultivators, and hunters. This is exercised through control over pastures and wells along the trekking routes and over some oases (Sweet, 1965) from which the noblemen extract dates and wheat yearly, either by force or as shares from their proprietary holdings.

It appears likely that such systems will erode under the influence of modern commerce and as a result of the growth of a centralized state structure that favors members of groups that are more sedentary and living in closer contact with the state representatives. Cole (1975) notes a change in Saudi Arabia where now the most influential herd owners are those with the largest sheep flocks, rather than those who own camels.

Political influence through "protection" diminishes in influence with the growth of the state, and predatory camel owners are possibly reduced to subsistence or commercial producers.

The future of camel pastoralism

The future of camel pastoralism seems to be at stake despite the wealth of technical knowledge and cultural accomplishments that it represents. The practical and political needs of camel nomads have long been neglected by national governments. Today, there is a growing interest among planners and researchers in the potential of the camel as a meat animal. It is hoped that their efforts to develop the camel industry will benefit the pastoral camel people, but it is not self- evident. The different goals of development do not necessarily go hand in hand. In fact, it is usual with livestock development efforts in the arid zone that the local pastoral producers are only one of the "target groups" involved in the development objective. Their rights to social and economic welfare tend to play a more important role in rhetoric at the planning and fund-raising stage than in formulating actual policies, while concern for national interests and the pressures from politically influential urban consumers and traders may be more decisive.

It is illuminating to draw parallels to cattle sector development in East Africa. A popular model for development is that of a stratified system whereby livestock produced in arid regions under traditional pastoralism are brought to commercial fattening ranches in areas with better grazing. Labor costs for the cow-calf operation are so high that it cannot be profitably pursued within the context of an enterprise relying on wage labor (don Kaufmann, 1976). Fattening requires less labor and is the part of the production process that has the highest capacity for profit, whether undertaken by the commercial rancher or the traditional pastoralist. This form of integration of traditional production with the modern beef industry gives little protection to the small primary producer but passes risks and cost on to him. Wealthy pastoralists who have the choice keep their animals until they are fully grown. Poor stock-owners, on the other hand, may have to sell whatever stock they have, irrespective of age and at a low price in order to cover urgent needs. The weakening of traditional systems and the subsequent impoverishment tends to start a vicious cycle of deteriorating husbandry practices, range degradation through decreased mobility, and lessened food production (Dahl and Hjort, 1979).

It is likely that the development of camel breeding will be similar to that concerned with commercialization of the cattle industry. As indicated above, camel reproduction under open range conditions is a difficult and labor-consuming process that may require intensive engagement of individual caretakers rather than cheap handling of camels en masse. A stratified system producing young animals for the beef market is also reminiscent of the common division between specialized camel-breeding groups and the far larger population who use camels. A major difficulty with improving the camel industry so as to benefit the nomads is to safeguard institutional forms that can maintain control of the fattening process. It must be borne in mind that camel nomads have for centuries been producing for a market. What will be the economic and ecological consequences of a meat market that withdraws stock from the market for loaders and work animals?

We should make clear that we are not advocating any attitude of paternalistic protectionism. That cultures are ancient or traditional is not alone a valid reason to maintain them unchanged, especially if the bearers of these cultures find a better way of life. But those who have the power to intervene in the systems of sustenance of others must remember to make a fair evaluation of the actual number of people employed and supported by the traditional system and the availability of other similarly efficient sources of subsistence. There is indeed need for more research on camels, and it is important that such research be geared to decreasing the risks to which pastoralists so far have been subject, rather than to promoting commercialization as a goal in itself. Much harm has already been done to those who care for camels, owing to the failure to acknowledge that they have animals with specific needs, separate from those of cattle, and that special provisions must be made for them when, for example, irrigation schemes and cattle development projects are planned. Modern science can also provide solutions to some of the disease problems that have hampered camel reproduction and health in the past; it can permit the camel economy to sustain and enlarge the population.

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The mountain nomads of Iran: Basseri and Bakhtiari

DOUGLAS L. JOHNSON

Nomadic tribal groups have held positions of great importance throughout all of Persian history. In keeping with the trend that is accelerating throughout the arid world, these groups have experienced a slow but steady decline in prestige, numbers, and influence since the middle of the twentieth century, but some segments of the various tribal groups are still migrating today. While nomads are found scattered throughout the entire country, the strongest and largest groups have been concentrated in the Zagros mountains. Much of the Zagros range remains marginal for agriculture, but it offers excellent possibilities for the development of a pastoral livelihood that is an important contributor to the national economy.' Despite often intensive governmental pressure to encourage the sedentarization of nomads, Basseri, Qashqai, Bakhtiari, and Lur nomads still set out each year on treks from their lowland winter quarters to summer pastures in the high mountains. A brief study of the migratory patterns of two of these groups follows a discussion of the physical environment to which their movements are related.

The physical environment

The mountain topography of the central Zagros is one of the two outstanding and striking features of the natural environment in which the nomads make their home. (2) The mountain system is composed of a series of parallel ridges of declining altitude; they run from the northwest to the southeast. Folding, rather than faulting, has been the major mechanism in the formation of these ridges, and as a result, they constitute a classic series of long anticlinal ridges separated by deep synclinal valleys. The ridges are densely packed everywhere, but in the north they are generally broad and high, whereas in the south they are small and fine. Outstanding dominant peaks are seldom found. Instead, there is a gradual increase in the altitude of the individual ridges from the south to the north, those in the south averaging about 600 m, while occasional ridge domes can be found in the north that are as high as 4,000-4,500 m.

Erosion, compounded by overgrazing and by overcutting of the forest, has resulted in deep, incised, and narrow river valleys. These rivers flow parallel to the mountain ridges in a grid pattern, except where they are able to break through the mountain barriers in a series of spectacular gaps and gorges called tangs. Through the tangs run the principal avenues into the interior. In certain locations streams are unable to pierce the anticline ridges and interior drainage basins, and associated swamps and shifting saline lakes are the result. Because of somewhat heavier precipitation, the mountain slopes in the northern areas are apt to have an oak forest cover, but farther south, where the rainfall is less abundant and where deforestation is more advanced, slopes of exposed rock in striking colors of red, yellow, white, gray, green, or black are common. (3) Valley floors are deep, may range from 1,200 to 2,500 m above sea level, and are covered by a park-like grass and shrub vegetation that is sharply contrasted with the denuded slopes above. It is upon these valley floors that the nomads of the region find the principal supply of grass along their seasonal migration routes.

Falling almost entirely in the winter months, precipitation is scanty; the lowest totals, generally around 500 mm, fall in Fars province. Precipitation amounts increase markedly as one goes up-slope and northward into the higher elevations. (4) Yet, except for these higher elevations and favored sites along perennial streams draining the higher mountains, aridity is the rule. This paucity of precipitation is due to the dominance of dry, hot, Indian monsoon air in the summer, and dry, cold, stable air flowing out of the Siberian anticyclone in the winter. Rain that does fall originates in the Mediterranean region in the form of cyclonic disturbances and is confined almost entirely to the winter season. At irregular intervals, the dominance of the Siberian anticyclone breaks down and Mediterranean cyclones advance across the Fertile Crescent towards the Zagros mountains. Most of the moisture is deposited in Syria and Iraq as rain, and upon the higher ridges of the northern Zagros as snow. Occasional cyclones are turned south by the Zagros barrier and retain enough moisture to support a rather scanty vegetation on the low ridges and hills along the Persian Gulf. Thus, precipitation decreases in quantity from the north to the south in rough correlation with the elevation of the mountain ridges.

Iran in general, and Fars in particular, experience a marked continentality in temperature regime, with high summer and cold winter temperatures being characteristic. This is an important feature of the climate since, when coupled with the marked seasonality in and variable geographic distribution of rainfall, it contributes in an important way to the seasonal availability or scarcity of pasturage.

The basseri

The Basseri are a group of tent-dwelling nomads in Fars province who sustain themselves by herding sheep and goats on a series of mountain ridges and valleys to the north, east, and south of the town of Shiraz. Their tribal territory runs in a continuous strip some 490 km wide from the coastal hills west of Lar near the Persian Gulf in the south to the high slopes and valleys around Kuh-e Bul Mountain in the north. Linguistically Persian, the Basseri form a distinct group in an ethnically diverse area. In 1958, the Basseri had from 2,000 to 3,000 tents, or a population of about 16,000 people. However, since the size of the tribe varies with the political fortunes of the chief and with the natural conditions of the area in any particular year, the numerical strength of the tribe can fluctuate significantly. (5) Indeed, at present, for a variety of reasons, the Basseri are experiencing a decline in numbers and, consequently, in importance.

Migratory Pattern of the Basseri: The Il-rah

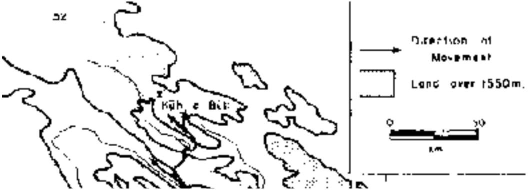
Sedentary agriculturalists are the dominant group in the area through which the Basseri migrate, and the Basseri migration route is also used by other tribes. In their migration, the Basseri travel in compact groups that are never widely dispersed over a large part of the tribal area, so that at any one time during the migration, the Basseri occupy only about an 80-km stretch of the area that they claim (figure 5-1). Although the Basseri claim to own the il-rah (migration route), use is shared with agriculturalists and with other migratory tribes. What ownership really means in the nomadic context is the right to exclusive usufruct of the particular section of the ilrah that the tribe happens to occupy at any particular time.

The Basseri claim the right to pass between summer and winter pastures in their strip of land, to draw water from natural sources, and to pasture their flocks on uncultivated land. The territory contained within the il-rah and the precise boundaries of the il-rah are quite vague. This is not important, however, since tribes move along their il-rah in a regular schedule and follow a particular path determined by the availability of grass, water, and mountain passes. The number of tribesmen using or passing through an area is adjusted to the carrying capacity of that area.

Within the tribe, the chief uses his authority to assign a particular sequence and division of land utilization among various sections of the tribe. He also exerts his authority, backed up by the political power of his entire tribe, to arrive at adjustments in the migration pattern vis--vis other tribes. Thus, the territory that the Basseri occupy at one time during the year may be the "property" another tribe later in the year. For example, the Kurdshuli tribe proceeds northwards ahead of the Basseri, while Arab, Basseri, and Qashqai tribes all arrive at the Mary Dasht valley at about the same time.

(6) Since a particular tribe follows the progressive development of pasture northwards, it is restrained by the pressure of maturing pastures ahead and withering pastures behind, as well as the pressure of other tribes preceding, following, or paralleling its line of march. According to Barth, The il-rah of a nomad tribe is thus a schedule of traditional rights to utilize certain places at certain times. These rights are also traditionally sub-divided and alloted within a tribe among its various sections, so alternative routes in the il-rah are held by different sections." (7) The result is a flexible system that can be adjusted to changes in the relative strength and importance of tribes and sections vis--vis each other.

The Migration Route: Utilization of Successive Pastures



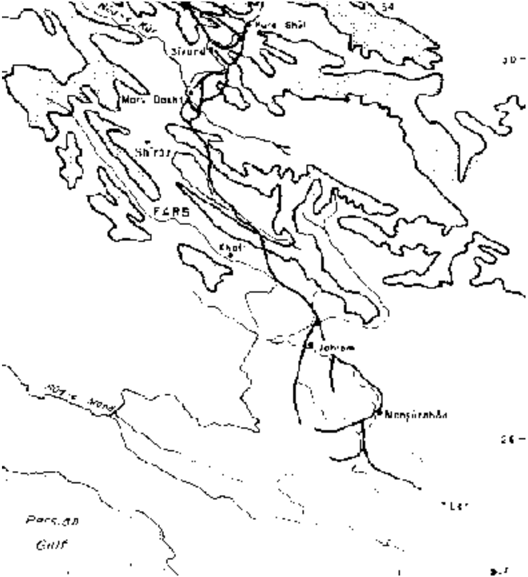


FIGURE 5 Basseri of Fars migration routes (after Barth, 1962).

In their pastoral exploitation of the natural environment, the Basseri are entirely dependent on the utilization of successively available pastures. Different sections of the tribal il-rah are grazed at different times during the year with the particular sequence being dependent on the availability of water and of grass. (8) The sheep raised by nomads (which are larger and more productive than those raised by the peasants) seem to be an equally important factor in initiating movement. The nomads' sheep are neither as resistant to cold as those of the northern mountain peasants nor are they as resistant to heat as those of the lowland peasants. Huge losses are common among the herds of tribesmen forced to settle for a full year in one place. This abnormally high rate of attrition would seem to indicate that the sheep raised by nomads are genetically adjusted to the utilization of pastures at varying altitudes in different times of the year in order to avoid climatic extremes. If so, migration is essential to the continued health and productivity of the sheep upon which the viability of the Basseri economy depends. (9)

During the winter months, the Basseri are widely dispersed in the low hill country near the Persian Gulf south of Jahrom and west of Lar. Although the higher valleys and mountain slopes to the north are covered by a blanket of snow, these southern hills are free from snowfall. Although winters are cool, they are not unbearable, and the occurence of cyclonic storms from the Mediterranean region is frequent enough to make the region fairly well-watered. The grass cover is sufficient to permit good grazing as long as the rains are plentiful, and the characteristic settlement pattern at this time of year is one of extreme dispersal. Families are scattered, singly or in very small herding units of two to five tents, on higher ground between the seasonal streams to avoid floods and wet lowlands.

March sees the beginning of movement towards the summer pastures. Pastures begin to dry up first in the lowlands, while pasturage in the middle altitudes is still quite good. Thus, in March the Basseri begin to move off the hills into the uncultivated valleys in the lowland area and congregate in the BenorouMansurabad plain. By the end of the Persian New Year celebrations (the spring equinox), this concentration is completed. All the nomads then move northward in succession, in camps of 10 to 40 tents, over a series of mountains and valleys past Jahrom, heading always towards the still-productive pastures of the north. By the end of June or the beginning of May, the Basseri reach the Mary Dasht plain. Here a bottleneck is apt to develop, since other tribes with large herds are passing through the area at the same time.

After crossing the Rud-e Bur by the Plu-e Kaha or Band-e Amir bridges or by ferries, the Basseri split into a number of groups to make the best possible use of the available pastures. In the last stage of the migration, the Basseri go as far as the upper reaches of the Rud-e Kur where some remain, while others continue on to the higher pastures on the slopes of the Kuh-e Bul mountain ridge.

By June, all sections of the Basseri are in their summer quarters. Above 2,000 m the pastures are good throughout the summer months, and it is unnecessary to move the camps, except for purely local shifts to escape campsites made filthy by prolonged animal concentration. As in the winter camps, the pattern here is one of dispersed settlement, but summer camps tend to be somewhat larger and closer together than those found in the winter lowlands. In exceptionally dry years, these mountain pastures may dry up, but usually there is enough stubble, bushes, and thistles to enable the animals to survive. In recent years, the nomads have taken to raising small quantities of grain in the summer pastures. (10) Usually this grain is planted by poor peasants living in villages owned by the more wealthy nomads and is sown in the spring before the Basseri arrive. The grain is then harvested before the return to the lowlands and does not constitute an important part of the nomadic economy.

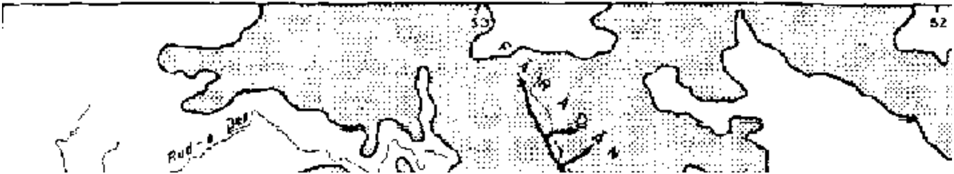
The return trip begins in August. After the desiccating heat of summer, pastures are poor everywhere. Consequently, the return trip to the winter pastures is more rapid than the spring migration. The wealthy nomads push south rapidly and arrive in the hills west of Lar by September. Those nomads who are less well-off economically stop for awhile and graze their herds on the postharvest stubble of the peasant fields around Mary Dasht. The temporary stop in the Mary Dasht plain is beneficial both to the nomads, who have an opportunity to seek seasonal agricultural employment at the height of the harvest season and thus supplement their income, and the peasants, who get not only the nomads' labor but also the fertilizer represented by the manure produced by the animals grazing on their fields. By midSeptember, this harvest work is past and the remaining nomads trek rapidly south, again dispersing into their winter quarters.

The bakhtiari

The Bakhtiari, divided into two major groups - the Haft-lang and Chehar-lang - are a powerful and cohesive tribal confederation in southwestern Iran. Stretching in a broad band through the central Zagros mountains, the Bakhtiari tribal territory (11) extends nearly 300 miles from its frontier with the Lur tribes at Dezful and Rude Dez to the winter camp grounds north and west of Ramhormoz. Although the tribal territory is not as wide as it is long, it reaches from the lowlands of Khuzestan over the crest of the 4,547-m Zard Kuh into the submontane valleys and basins of western Esfahan province on the fringes of the central Iranian plateau. The Bakhtiari area, while mountainous, rugged, and oft-times sterile, does offer the typical altitudinal range of climate and vegetation upon which all of the nomadic systems of the Zagros are based.

Despite some confusion and a disappointing lack of specific information about Bakhtiari pastoral movements, (12) the general outline of the pattern is well known and replicates patterns found elsewhere in the Zagros mountains (figure 5-2). The winter months are spent in the lowland foothills and plains of norther Khozestan between Dezful and Ramhormoz, (13) with the Haft-lang concentrated around Dezful and the Chehar-lang scattered from Shushtar to Ramhormoz. Dispersion during the winter months is extreme, with groups of three or four tents being scattered throughout the lowlands (14) in a pattern also noted among the Basseri.

Sometime between the vernal equinox (15) and mid-April, (16) the scattered winter minimal camp groups begin to move northward, away from the drying lowlands towards their upland summer pastures. Evidently an entire tribal subdivision does not begin to move simultaneously; rather, tent groups move initially in an isolated fashion gradually coalescing into larger groups as the difficulty of the terrain increases and the available routes of passage decrease. (17) In some favored mountain valley at some time during the initial stages of the trek, the tent groups will come together and the sub-tribe will continue the movement as a unit, crossing the Zard Kuh range until once again dispersing in the upland valleys and basins that eventually slope down to the central Iranian plateau.



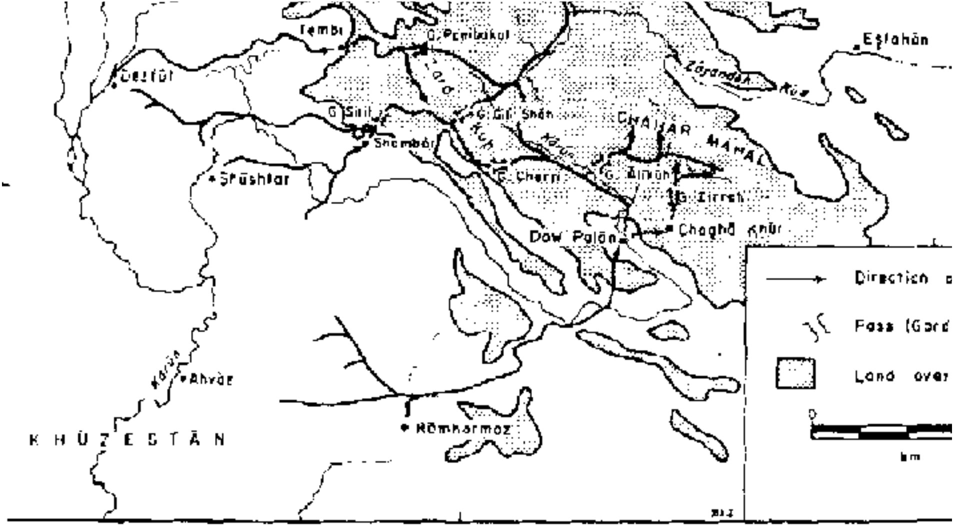


FIGURE 5-2 Bakhtiari pastoral movements.

While there is general agreement about the nature of this summer upslope, winter downslope movement, and while there is a consensus that movement proceeds in a zigzag fashion utilizing valley bottoms and favorable passes, much ambiguity still persists. De Bode provides a list of summer and winter encampments that indicates that the Chehar-lang spend their summer near the sources of the Zayandeh Rud in the Zard Kuh range as well as in the district of Faradan (with minor groups in Chahar Mahal), while the Haft-lang spend their summer in Chahar Mahal and near the sources of the Karun River in Zard Kuh. (18) However, he fails to indicate the routes followed, aside from a cryptic comment that a tendency to cross each other's path often leads to conflict between the two groups. Coon asserts that there is only one practical route through the Bakhtiari country and that the entire tribe, therefore, must move as a unit along this route twice each year. (19) De Morgan also describes only one Bakhtiari migration route (it crosses the Rud-e Dez by a bridge after descending from the uplands via the pass at Badouch), but he gives no clear indication that this is the only route utilized by the Bakhtiari. (20) In contrast, Cooper states that there are five routes through the Bakhtiari mountains,

(21) a number cited by several other writers. Yet Cooper traveled only one of those routes, the most rugged of the five, one that is used by only a small portion of Bakhtiari, and his description of that route is too vague to permit positive identification. Sawyer also mentions five ways across the mountains, but he only specifies four - the God-e Murda (a pass that fails to appear on most maps of the area) and Cherri passes on the two main roads from Shushtar to Esfahan, and Gili Shah and Pambakal passes across Zard Kuh. (22)

Despite the confusion present in the literature as to which routes are followed, some definite conclusions about migration tracks can be ascertained. The most commonly mentioned route, used exclusively by the Haft-lang, is the old caravan route from Ahvaz to Esfahan. (23) This trail, called the Lynch Road, crosses the Rudkhaneh-e Jarrahi north of Ramhormoz, passes over the outlying Zagros ranges, and descends to the Karun valley. After cutting off a loop of the Karun, the road continues to Dow Polan where a split occurs. Those groups summering in Chahar Mahal cross the Karun and proceed westward to Chagha Khur before turning northward, entering Chahar Mahal via the pass (gadang) at Zirreh. (24) The majority of the Haft-lang continue up the Karun along the eastern slopes of Zard Kuh. In the upper reaches of the Karun directly east of Gili Shah pass is a notch, the remnants of an ancient attempt to divert the Karun into the headwaters of the Zayandeh Rud, where it is relatively easy to cross the last mountain barrier. (25) Once across this range, the Haft-lang are in the valley of the Zayandeh Rud, which offers an easy passage to the summer pastures in Faradan.

The other major Haft-lang route (there may well be others unknown to Europeans) traverses the central portion of the Bakhtiari area. (26) This road leaves from the Shushtar area, crosses the Karun, and wends its way along mountain valleys and across numerous passes to the tribal staging area in the Shambar valley. From here, the trail crosses the gadang at Silili before crossing Zard Kuh at either Pambakal or Gili Shah. (27) At this point, the Bakhtiari from Shushtar join those proceeding up the Karun from Ramhormoz and follow the course of the Zayandeh Rud to Faradan.

The Chahar-lang, the smaller and weaker of the two Bakhtiari sections, begin their migration from around Dezful. Evidently, some of the Chahar-lang follow the same route as do the Haft-lang from the Shushtar area, since Cooper, who traveled with the Baba Ahmadi (a group that winters around Dezful), passed through the Shambar valley on his way to Chahar Mahal. (28) Other Haft-lang sections proceed either up the left bank of Rud-e Dez, and thence through the headwaters of the Rud-e Shur via Tembi to the northwest flank of Zard Kuh at Gardan Pambakal, or journey somewhat closer to the Karun through Chilau and over the southern passes of the Zard Kuh. (29) Since the majority of the Haft-lang summer in Faradan, their path crosses that of the Chahar-lang, the majority of whom summer in Chahar Mahal, and disputes over the right-of-way probably account for the mutual hostility of the two groups mentioned by de Bode. Once across Zard Kuh, those sections going to Faradan follow the Haft-lang route down the Zayandeh Rud, while the majority of the Chahar-lang enter Chahar Mahal through the Alikuh pass over Kuh-e Saldaran. (30)

Once over the major mountain barriers, the Bakhtiari spread out into their upland pastures. While some of the Bakhtiari clans are sedentary, the majority are nomadic, and agriculture forms only a minor part of their economic life. Despite this fact, it is not uncommon to find nomadic Bakhtiari sowing wheat and barley in both their summer and winter quarters as a needed adjunct to their pastoral activities. (31) Autumn and the onset of cooler temperatures signals the return to lowland grazing and the clans retrace their steps downslope over the same routes used in their ascent.

In conclusion, while information on the Bakhtiari is surprisingly limited considering the former power and importance of the group, enough data is available to indicate the nature and the pattern of their migratory regime. Despite the impossibility of identifying which tribal clans use which available routes and the difficulty in ascertaining the precise number of routes that can be used, it is obvious that certain subsections follow traditional paths. Cooper, for example, traveled with the Baba Ahmadi tribe over the Zard Kuh range from the Jungari district in Khuzestan to Chahar Mahal, while the Haft-lang are largely restricted in their migrations to the Karun River basin. Because avenues of passage are limited to river valleys and mountain passes, the movement is restricted to a limited number of possible routes and it thus has a very definite and clear linear, constricted pattern on the map. This strong linear pattern, coupled with a marked seasonal oscillation between summer and winter pastures, characterizes all groups of mountain nomads.

NOTES

1. See Thomas R. Stauffer, "The Economics of Nomadism in Iran," Middle East Journal XIX:284-302 (1965). Fredrik Barth, "Nomadism in the Mountain and Plateau Areas of South West Asia," in The Problems of the Arid Zone (Paris: UNESCO, 1962), pp. 341-355, also argues that the nomad is often the best possible exploiter of

areas that are too marginal for agricultural use, unless governments are ready to invest capital expenditures grossly disproportionate to the possible returns.

2. The best general account of the physical characteristics of the area is found in Theodore Oberlander, The Zagros Streams: A New Interpretation of Transverse Drainage in an Orogenic Zone (Syracuse Geographical Series No. 1; Syracuse: Syracuse University Press, 1965).

Also worthy of mention are the travel-oriented writings of: C. J. Edmonds, "Luristan: Pish-i-kuh and Bala Gariveh," Geographical Journal LIX:335-356 and 437-453 (1922); J. V. Harrison, "The Bakhtiari Country, Southwestern Persia," Geographical Journal LXXX:193-210 (1932); F. R. Maunsell, "The Land of Elam," Geographical Journal LXV:432-437 (1925); and H. A. Sawyer, "The Bakhtiari Mountains and Upper Elam," Geographical Journal IV:481-505 (1894), all of which devote the major portion of their attention to a description of the topography of the Zagros mountains.

3 For a detailed description of the vegetation of Iran, see Hans Bobek, Die natrlichen Wlter und Gehlzfluren Irans, (Bonner Geographische Abhandlungen, Journal 8 (1951), and idem, "Klima und Landschaft Irans in vorund frhgeschichtlicher Zeit," Geographischer Jahresbericht aus Osterreich XXV:42 (1953-1954). A more recent reconstruction of the original vegetation cover of Iran is M. Zohary's "On the Geobotanical Structure of Iran," Bulletin of the Research Council of Israel, Supplement to Volume 11D (1963).

4. M. H. Ganji, "The climate of Iran," Bulletin de la Socit de Geographie d'Egypte XXVIII:195-299 (1956), has an excellent series of maps that point out this pattern.

5. G. Demorgny, "Les reformes administratives en Perse: Les tribus du Fars," Revue de Monde Musulman XXII 85-150 (1973), indicates just how extensive such shifts can be, for he describes (p. 105) the

Basseri as a tribe of peaceful agriculturalists. His map (Carte No. 2, end-papers) demonstrates that migrations also were once of much smaller amplitude than at present.

6. Fredrik Barth, "The Land Use Patterns of Migratory Tribes of South Persia," Norsk Geografish Tidsskrift XVII:4 (1960).

7. Ibid., pp. 7-8.

8. Barth, Nomads of South Persia, pp. 4-6, is the best if not the only, source on the Basseri migration pattern.

9. Ibid., pp. 6-7.

10. Ibid., p. 9.

11. See Clement de Bode, Travels in Luristan and Arabistan (London: J. Madden and Co., 1845), p. 77, an invaluable source on southwest Persia, as well as Harrison, "The Bakhtiari Country, Southwestern Persia," p. 193; Sawyer, "The Bakhtiari Mountains

and Upper Elam," pp. 481-482; and Sir Arnold T. Wilson, "The Bakhtiaris," Journal of the Royal Central Asin Society X111:205-225 (1926). There is some confusion as to the precise boundaries of the Bakhtiari area, but there is general agreement in placing the Bakhtiari between the Lurs and the Qashqai. However, this is only partially true, for the Atlas Narodov Mira, (Moscow: Glavnoe Upravelerie Geodezii, Kartografii, 1964). pp. 70-71, shows the Bakhtiari and Qashgai tribal territories adjoining in their upland summer quarters, but being separated from each other in their lowland winter quarters by a solid block of sedentary Lurs.

12. None of the written materials dealing with the Bakhtiari give detailed data on the specific routes followed during a seasonal cycle. The most striking example of this deficiency is the effort of Merian C. Cooper, Grass (New York: G.P. Putnam's Sons, 1928). While Cooper's description of Bakhtiari movement is graphic and his photography is excellent, he migrated with only one minor group, mentions nothing on movements of other groups, draws no maps, and seems to regard the specifics of place names and location as

non-essential information easily dispensed with. The best source for the Bakhtiari remains the now dated work of Clement de Bode.

13. De Bode, Travels in Luristan and Arabistan pp. 82-83; Wilson, "The Bakhtiaris," p. 208; and Cooper, Grass, pp. 9-10.

14. See Cooper, pp. 131-135, for a description of this winter dispersion.

15. Wilson, "The Bakhtiaris," p. 208.

16. Cooper, Grass p. 195.

17. Ibid., p. 195.

18. Carleton S. Coon, Caravan: The Story of the Middle East (New York: Holt, Rinehart and Winston, 1965), p. 219.

19. De Bode, Travels in Luristan and Arabistan p. 77.

20. Jacques de Morgan, Mission scientifique en Per&e (Paris: E. Leroux, 1894-1904), II:200.

21. Cooper, Grass, p. 212.

22. Sawyer, The Bakhtiari Mountains and Upper Elam.

23. J. V. Harrison, "Some Routes in Southern Iran," Geographical Journal XCIX:120, 122 (1942),; and Cooper, Grass, p. 41.

24. Sawyer, "The Bakhtiari Mountains and Upper Elam," map, end papers.

25. Harrison, "Some Routes in Southern Iran," p. 126.

26. Harrison, "The Bakhtiari Country," pp. 194-199; and idem, "Some Routes in Southern Iran," p. 125.

27. Harrison, "The Bakhtiari Country," p. 197.

28. Sawyer, "The Bakhtiari Mountains and Upper Elam," p. 493.

29. Cooper, Grass, p. 245.

30. Harrison, "Some Routes in Southern Iran," p. 216.

31. Sawyer, "The Bakhtiari Mountains and Upper Elam," map, end papers.

32. Wilson, "The Bakhtiaris," p. 208.

The Marri Baluch of Pakistan

DOUGLAS J. JOHNSON

The Baluchi tribes, mingled with large numbers of culturally akin Brahui, stretch over the vast, barren, underpopulated region known as Baluchistan. Unfortunately the recipients of little detailed study, (1) the Baluchi range far afield, some groups being reported as far north as the Harat area. (2) The only systematic study was conducted by Pehrson, (3) who deals with the Marri Baluch. This group dwells in a hilly, broken area at the northeast end of the Baluchi-inhabited territory near the Afghanistan-Pakistan border, and is separated from the main grouping of Baluchi tribes of Makran and Chagai and from the Brahui tribes of Kalat by the non-Baluchi and non tribal areas of the Sibi basin. North of the Marri area are found the Luni and Kakar Pathan agriculturalists as well as the Afghani powindah nomads who occupy the northern region during the winter. The Marri are cut off from direct access to the Indus valley by the Khetrans, speakers of their own peculiar dialect, and are bound to the south by the Bugti Baluch, traditional enemies of the Marri.

Physical environment

While the Sibi basin and the Indus valley lowland are extremely flat, featureless plains, the Marri area, a tangled mass of limestone hills and narrow valleys, is a complete contrast. Except for the Sulaiman range, which has a north-south axis and overlooks the

Indus valley, the main trend of the ridges is east-west. Valley bottoms and plateaus in the main Marri tribal area vary from 800 to 1,000 m in elevation, while hill elevations gradually increase from 1,000 m in the south to over 3,000 m in the Pathan districts to the north. Passes are few and widely scattered and passage from one valley to the next is often a problem. The result is a confused drainage pattern, the east slopes of the Sulaiman mountains draining directly to the Indus, whereas the remainder of the surface runoff is discharged toward the southwest into the plains around Sibi.

Most of these streams flow during no more than two months of the year (July and August), and the seasonal nature of the stream flow is directly related to the paucity of the region's precipitation. Rainfall totals are low, averaging 75-125 mm in the lowlands, while totals as high as 300 mm have been recorded under orographic conditions in the northern mountains. (5) Although rain occasionally falls in winter - the result of very infrequent cyclonic storms of low moisture content that drift in from the eastern

Mediterranean - the main rainfall occurs in July, August, and early September. Coming at the end of the summer monsoon, this rain, sporadic in distribution and violent in character, falls in the form of torrential thunder showers that give rise to heavyflooding. Although streams flow only during part of the year, subsurface water in streambeds is usually available with only a small amount of digging.

Not only is rainfall sporadic in distribution and sparse in quantity, but it also occurs during the hottest part of the year, thus lessening its effectiveness. Temperatures in excess of 50°C are not uncommon in the Sibi plains during the summer. Highland temperatures tend to be cool in summer and cold in winter, so that a marked daily and seasonal temperature range is characteristic. The combination of high temperatures and low rainfall totals produces a scanty vegetation cover, and vegetation, like temperature conditions, tends to be distributed aptitudinally. (6) On the higher elevations are found scattered stands of juniper, pistachio, ash, and wild almond, while acacias (Acacia nilotica, A.

modesta), olives, and occasional poplar (Populus euphratica), (7) blue gum (Eucalyptus), and willow trees are found in the lower hills. In the valleys, dwarf palm (Nannorrhops ritchieana), tamarisk (Tamarix indica), Zizyphus nummularia, and occasional myrtle groves are common. Annual grasses and herbs are scattered everywhere, and it is their fluorescence in late spring and continued presence in summer, together with that of the trees and shrubs, that give the area its best pastures. (8)

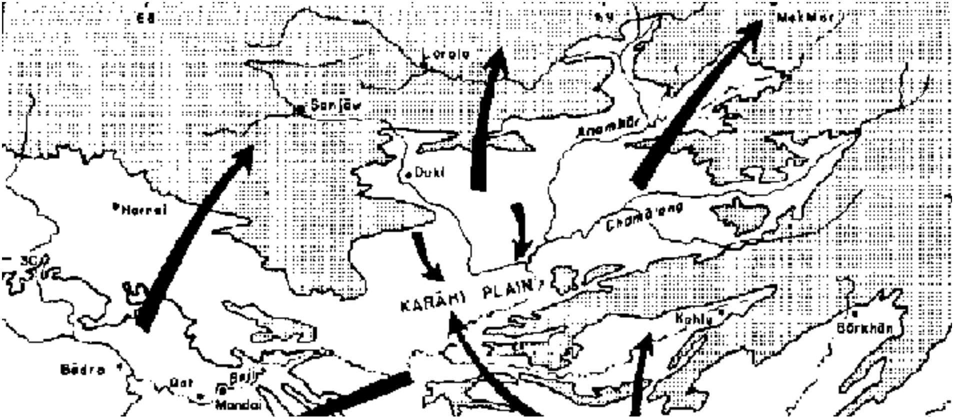
Seasons and migrations

Early statements on the nature of the Baluchi-Brahui pastoral system fail to deal with the question of seasonal migrations in concrete and precise terms. Pottinger, for example, describes the Baluchi as being a pastoral people who remain within a relatively restricted area. (9) On the other hand, he believes the Brahui to be "a still more unsettled wandering nation, always residing in one part of the country during the summer, and emigrating to another for the winter season; they likewise change their immediate place of abode many times every year in quest of pasturage for their flocks." (10)

The Imperial Gazetteer is somewhat more specific about the Brahui regime, suggesting that the movement from highland to lowlands and vice versa was in part conditioned by a desire to escape temperature extremes and in part by employment as seasonal agricultural workers at harvest time. (11) Spooner foreshadowed an explanation when he suggested that upslope-downdope movement was coupled to periodic visits to grain fields and date groves, as well as to somewhat irregular movement of the household units and herds in response to a varying pattern of rainfall distribution. (12) However, it was not until the appearance of Pehrson's study of the Marri Baluch and Barth's continuation of Pehrson's work (13) that an ecological explanation of an apparently vague, complex, and seemingly random system was developed (figure 6-1).

A mixed economic system

Faced with a harsh, inhospitable, and marginal environment, the Marri have evolved a complicated subsistence system that mixes a variety of exploitive techniques that are difficult to combine in an attempt to maximize returns. (14) As a result, Marri household units engage in herding, agriculture (generally dry farming), wage labor, and collecting in proportions that vary from group to group.



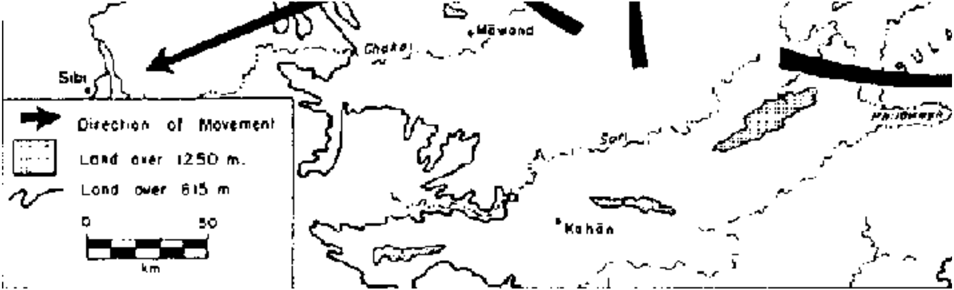


FIGURE 6-1 Marri Baluch migration routes (after Barth, 1964).

Herding usually forms the most important activity, with a wide variety of animals being kept. Sheep and goats are the most important animals herded, their meat and wool being sold, but milk and other dairy products, because of taboos against their sale to outsiders, are consumed within the family. (15) Donkeys and camels are the major baggage animals, although the rough and stony nature of the Marri tribal area is hard on camels and generally restricts their possession to the rich, who keep their camel herds outside the tribal area in the lowlands of Sind. Horses are kept by the wealthy as a prestige symbol, while cows are retained only in sufficiently large quantities to ensure an adequate supply of agricultural bullocks. The best pasture for cattle and sheep is from April on into summer, while at other times all animals must subsist on dry fodder. Water is often a problem, since sheep must be watered three times a day in hot weather, and once a day in cool weather, whereas goats must have water once a day in hot weather, and every other day during the cool season.

Agriculture, almost exclusively dry-farming of barley and wheat, also forms an important part of the Marri pattern. Whereas pasture land is the collective possession of the tribe and thus open to use by any Marri, ownership of agricultural land is vested in individual tribal sections. (16) Within the tribal section, land is allotted on an equal basis to each male member, regardless of age, for use during a 10year period. Since efforts are made to ensure equality in land quality, these plots are scattered widely about the Marri area. Moreover, as population increases, there is a definite tendency to increase the amount of land devoted to agriculture, and at the same time to encroach on the common pasture traditionally reserved for all Marri. This withdrawal of agricultural land diminishes pastoral reserves and forces Marris, all of whom want to retain a mixture of agriculture and animal husbandry in order to balance their diet, to search for pasturage in areas outside the Marri tribal territory. Thus, a slow but steady expansion into the Pathan areas to the north has been taking place, abated by the superior military and social organization of the Marri. (17)

The relative weight that a particular household unit assigns to herding as opposed to agriculture determines the particular economy and degree of mobility which that unit possesses. At one end of the continuum are the sedentary populations, primarily concerned with dry farming (although they may keep a few sheep and goats) and attached to a small number of towns and a somewhat larger number of semipermanent agricultural villages, whose fortunes fluctuate both with climate and with the success or failure of local political leaders. (18) Grouped around each town or village is a varying number of darshin nomads. These nomads move within a restricted area about 20 km in radius centered on the village, and are kept within the local area by relatively small herd size, a relatively large stake in village agriculture as wage laborers and as farmers in their own right, and by their need for a market for their animal products and a procurement center for trade goods. On the other end of the continuum are the powindahs, relatively free-moving nomadic camps unattached to a particular village. Marri nomadic camping units, whether darshin or powindah, are small, scattered, and can range from one to eight families, but generally number three to four. Powindahs are distinguished from darshin nomads by their longer migrations and greater herd size, (19) but this distinction, as well as the distinction between sedentary agriculturalist and darshin nomad, should not be regarded as absolute. Loss of herds through disease or other natural calamities, as well as the development of political and economic ties with a village, can change a powindah into a darshin or a sedentary, just as an increase in herd size may transform a darshin into a powindah. Thus, the situation is not stable, but rather is dynamic, with a great deal of movement from one group to another.

Another result of the different relative weight assigned to agriculture and the varying requirements of the different species in the camp herds is a marked spatial separation of the various camp functions. Since each activity has its own optimal pattern and cycle of movement, individual members of a camp will be scattered far and wide across the landscape. (20)

Because agricultural land is located in areas unsuited or undesirable for grazing and because individuals may be assigned or may lease land anywhere in the tribal territory, the men, who do most of the plowing and agricultural work, will often be found for extended periods at great distances from the camping unit. Care of the animals dominates the daily camp rhythm, and because different species have different water and forage requirements and preferences, they are herded separately. Shepherds are usually males, the young men herding the adult sheep and goats in the higher hills and mountain ranges, while young children guard the lambs and kids, usually keeping them near the camp. Women, children, and old men are in charge of the cattle and donkeys. Since the various herds leave the camp in the early morning, move through their separate orbits during the day, and do not return until night, the camp is largely deserted, particularly by the males, during the course of the day. Women have various gathering tasks that take them from the immediate vicinity of the camp, while the men of the camp are also often away buying and trading, hunting, searching for new pastures, or attending to political responsibilities. With so many activities of a disparate nature going on, the result is to "exert partly conflicting pulls on those participating. Any migration policy will be a compromise between these different pulls" (21) to be determined in the face of imperfect knowledge of precipitation, labor markets, and political relations, and only after a great deal of debate. In such a situation, despite the regularizing limitations of habit and previous experience, much variation in migratory movement at the camp level from year to year is to be expected and does in fact occur. (22)

Coupled with the high degree of flexibility in and variability of movement at the camp level is an apparently bewildering variety of movements at the tribal level. (23) During the hot months of summer there is a general northward shift toward higher elevations that brings Marri camps out of their tribal territory and into the Pathan regions around Sanjawi, Loralai, and Mekhtar. A similar movement north into the northwest Marri area or the southwest Pathan area is undertaken by Marri groups who winter in the plains around Sibi. However, at the same time there is a drift southward by camps in northern Marri areas into the Kohlu valley and surrounding areas; this meets a contrasting northward drift of camps from the extreme south. To further complicate the pattern, there is also a summer movement of scattered camps southward into the surrounding lowlands.

These apparently contradictory movements can best be explained by a concept of niches. (24) The Marri, because of their mixed agricultural and pastoral economy, are able to effectively occupy all of their niche, while they are blocked in any directly southward movement by the Bugti, who practice an identical mixed economy. To the north, the sedentary Pathan and nomadic powindahs exploit two separate halves of the same niche. (25) Either because of an inferior power position vis--vis the powindahs, or because of a desire to establish a mutually symbiotic relationship with them, or because of lack of inclination or opportunity, the northern sedentary Pathans keep few animals. Thus, when the powindahs leave on their summer trek to central Afghanistan, a niche is open for exploitation, and the Marri move in to fill it. Rent must be paid to the Pathans for use of the grazing, but, since it is generally the wealthier Marri with an almost exclusive emphasis on herding (the traditional role of agriculture being frequently neglected among wealthy Marri with large herds) who move in, the cost of grazing is not an insufferable burden. Since they are able to use relatively abundant pasture during the year's best rainfall in a zone having a cool temperature and a minimum of competition for pasture, the arrangement is an advantageous one. With the arrival of winter, the powindahs return from the north and reoccupy their winter quarters. Since the Marri and the powindahs are traditional enemies and the Marri sheep are less tolerant of cold than are those of the powindahs, the Marri are forced to fall back on their tribal lands or to the Khetran lands around Karkhana. (26)

Movement east and southwest into Sind represents a symbiotic response to the lowland agriculturalists' need for labor to harvest crops and clean irrigation ditches. Although this offers an opportunity for Marri to earn cash and increase their flocks in an area with few pastoralists, it interferes with the Marri's own agricultural practices and so represents an alternative largely restricted to the impoverished, who have small flocks and little seed. (27) The seasonal migration of Marri groups from the hot Sind plains into the Marri and Pathan highlands seems to represent a miniature powindah pattern; (28) groups that occupy the central valley during summer adhere to the traditional mixed agriculturalpastoral system, which means that long-distance movement outside tribal territories would impose an intolerable burden in commuting to their agricultural holdings. Finally, concentration in the central valleys is reputed to be due to more reliable monsoon rain there. (29) However, if the monsoon rains fail, these groups, as well as those that remain in the south near Kahan, move south into the Sindhi plains where their more heat-resistant stock has a better chance of survival and where water is available in poorly drained areas and along irrigation canals.

Conclusiones

The overall pattern of Marri pastoralism can be defined with reasonable accuracy. It is a system that allows a great deal of flexibility both at the camp level - to accommodate the different demands of a variety of animals and scattered agricultural holdings - and at the tribal level, where a flexible response to a sporadic rainfall and scattered pasture makes possible the occupation of open ecological niches. The system is characterized by a general lowland-to-highland movement in summer, although the movement to Sind and to the central valleys complicates the picture. Despite the fact that data is not available for the study of movements of individual camp units, it is reasonable to suppose that movement of individual camping units would be fairly constricted, since passage through the country is largely restricted to valley bottoms and infrequent passes as the herding units oscillate between their summer and winter pastures. While individual families from one clan may participate in a variety of possible patterns, the system at the tribal level remains one of rational and ordered utilization of the possibilities of the environment.

NOTES

1. See, for example, the interesting, but uneven, general historical survey of Muhammed Sardar Khan Baluch, Hi&tory of the Baluch Race and Baluchistan (n.p.:n.d.). Also having some limited usefulness are works such as Mansel L. Dames, The Baloch Race (London: Royal Asiatic Society, 1904), an attempt to evaluate various theories about Baluchi origin and migrations and reconcile them, as well as travel accounts such as Edward E. Oliver, Across the Border, or Pathan and Biloch (London: Champman and Hall, 1890), or Henry Pottinger, Travels in Beloochistan and Sinde

(London: Longman, Hurst, Reea, Orme and Brown, 1816). While excellent for background information, studies of this type usually provide little of solid value to the scholar with particularized interests. Even where detailed work exists, it is often so narrowly focused as to provide little additional information. Instances of this type are Klaus Ferdinand, "The Baluchiatan Barrel-Vaulted Tent and its Affinities," Tolk 1:27-50 (1959), a detailed study of the Baluchi tent, and Siro Kitamura ted.), Plants of West Pakistan and Afghanistan (Kyoto, 1964), essentially a catalogue of plants that lacks any reference to their potential utility for grazing or other activities.

2. W. Ivanov, "Notes on the Ethnology of Khurasan," Geographical Journal LVll:143-158 (1926), says a few words about the Baluchi nomads but does not give enough information to even begin to work out the migration patterns of these northern Baluch.

3. Robert N. Pehrson, The Social Organization of the Marri Baluch (Viking Fund Publications in Anthropology No. 43; Fredrik Barth,

compiler; New York: Wenner-Gren Foundation for Anthropological Research, Inc., 1965). The author lived with a small nomadic camp while doing 0a field work and died in the field leaving 0a notes to be analyzed by Fredrik Barth. As a result, the data is not quite as complete as it might otherwise have been, particularly in regard to the detailed seasonal movements of the individual nomadic camp. However, as the best available source, Pehrson'a study provides the basic information for this case study.

4. Despite being now somewhat out of date, by far the best source discussing the physical environment of the Marri continues to be the "Baluchistan," Imperial Gazetteer of India (Calcutta: Superintendent of Government Printing, 1908).

5. Ibid., p. 139.

6. See ibid., for perennial species and their distribution.

7. Ibid., p. 110.

8. Pehrson, Marrs Baluch, p. 1.

9. Pottinger, Travels in Beloochistan and Sinde, pp. 61-62.

10. Ibid., p. 70.

11. Imperial Gazetteer of India, "Baluchistan," p. 24.

12. Brian Spooner, "Kuch U Baluch and Ichtyophagi," Iran 11:63 (1964).

13. Fredrik Barth, "Competition and Symbiosis in North East Baluchistan," Folk VI:15-22 (1964).

14. Pehrson, Marri Baluch, p. 5.

15. Ibid., p. 5.

16. Barth, "Competition and Symbiosis," p. 19.

17. Fredrik Barth, "Ethnic on the Pathan-Baluch Boundary, Indo-

Iranica (Festschrift Morgensterne) (Wiesbaden: Otto Harrassowitz, 1964), pp. 13-20.

18. See Pehrson, Marri Baluch, pp. 11-12, for a more detailed treatment of the various residence forms that characterize Marri society.

19. Pehrson (ibid., p. 14) suggests that when a herd reaches about 100 animals, all other considerations become of secondary importance, and the camp then detaches itself from any particular village in order to have greater freedom to move in search of water and pasture.

20. Ibid., pp. 6-7 and 76-79.

21. Ibid., p. 77.

22. Ibid., p. 15.

23. Barth, "Competition and Symbiosis," pp. 15-22; and Pehrson,

Marri Baluch, pp. 15-16.

24. Barth (ibid., p. 17) argues that any particular environment or niche offers a certain amount of exploitable organic energy. Because exploitation of a niche is conditioned by the culture and technology that a particular group can bring to bear, it is conceivable that a given culture will not be able to use the full organic potential of its niche. Into the gap thus created other groups may possibly move, until the full limit of that particular niche is utilized. For a further example of this niche concept, see Fredrik Barth, "Ecologic Relationships of Ethnic Groups in Swat, North Pakistan," American Anthropologist LVIIl:1079-1089 (1956); and Bruno Fautz, Sozialstruktur und Bodennutzung in der Kulturlandechaft de. Swat (Nordweethimalaya), Gieseener Geographische Schriften 3, 1963). Here the Kohistani transhumants are unable to keep enough animals (due to severe winters and inadequate stabling and forage during the winter months) to completely occupy all of the available high mountain pasture during the summer. The Gujars, a nomadic group, are able

to take advantage of this situation and move up the river valley in a restricted oscillatory pattern typical of the Zagros Mountain nomadism and spread out over the upland meadows, thus utilizing a niche that otherwise would be neglected.

25. Barth, "Competition and Symbiosis," p. 18ff.

26. Pehrson, Marri Baluch, p. 16.

27. Barth, "Competition and Symbiosis,' p. 20.

28. Ibid., p. 21.

29. Ibid., p. 17.

30. Pehrson, Marri Baluch, p. 15.

Changing patterns of resource use in the Bedthi-Aghanashini valleys of Karnataka state, India

MADHAV GADGIL

Introduction

Indian society is among the most heterogeneous in the world - one in which hunter-gatherers and mechanized fishing trawlers, subsistence agriculturists and commercial plantation owners, village blacksmiths and modern steel mill workers live side by side. It is an agglomeration of tens of thousands of endogamous castes, a significant proportion of which still pursue a traditional hereditary pattern of subsistence, be it nomadic sheep grazing, basket weaving, or shifting cultivation. Many others, especially from the trading and priestly castes, have shifted to the modern sectors. This situation has led to a great variety of demands on the natural resources of the land; thus, the basket weavers need bamboo to weave mats, and industry needs bamboo as a raw material for paper; the peasants want river valleys to grow rice, whereas industry wants them to generate hydroelectric power. While these demands are mounting, acute shortages are developing, resulting in a whole range of adjustments, collusion, and conflicts over access to resources. I shall attempt to illustrate these with the help of a case study from a hilly region of peninsular India, where we have been working over the last decade (Prasad et al., 1985). Much of the information recorded here is based on personal observations and extensive interviews in the field over this period.

The setting

The Locale

The hill chain of the Western Ghats runs just inland of the west coast of India from the southern tip of the peninsula at 8°N all the way to the Tapi River at 21°N. Towards its middle, between 14°N and 15°N, the coastline is at its narrowest, with spur hills running right up to the sea. This part of the Western Ghats constitutes the Uttara Kannada District (also known as North Canara) of the state of Karnataka, a tract of low undulating hills rising up to 600 m, the level of the Peninsular Indian Plateau, and sloping rather gently towards the west coast, over a broad stretch of 80 km. The annual precipitation ranges from 2,000 mm to 5,000 mm and is largely restricted to the months of June through October, the period of southwest monsoon. The rivers of the tract are relatively short, with lengths of less than 100 km; they run westward from the hills to the Arabian Sea. They are in spate during the monsoon, but have little water during the rest of the year; the smaller streams run totally dry. In the middle of this region run two rivers - Bedthi and Aghanashini; their contiguous catchment areas of about 2,000 km^2 are the focus of this case study (Campbell, 1883).

Plant and Animal Life

The natural vegetation of the tract includes low mangrove forest at the mouths of the Bedthi and Aghanashini rivers; evergreen forests grow on the coast, the western face of the Western Ghats, and on the crestline with annual precipitation of over 3,000 mm; a semi evergreen and moist deciduous vegetation is found to the east of the crestline where precipitation reaches about 2,000 mm. The evergreen forests are economically notable: many species produce secondary chemical compounds of value including spices (pepper, cinnamon, and nutmeg) and drugs (reserpine). They also harbor wild mango and jackfruit trees. The evergreen trees have largely soft wood; the deciduous trees, on the other hand, often produce excellent timber, including the famous Canara teak.

The natural animal life is varied and abundant, and includes elephant, the Indian bison, spotted deer, tiger, grey langur and bonnet macaque, flying fox and flying squirrels, the great Indian hornbill, and peafowl (Prasad et al., 1979). The fresh waters, the estuaries, and the sea also abound in fish, prawns, and shellfish.

There are leeches, ticks, and mosquitoes as well, and much of this tract was highly malarial until the disease was controlled shortly after the Second World War (Gadgill and Mahlotra, 1982).

Agriculture

Cultivation of paddy in fields kept flooded with water during the monsoon is the dominant form of agriculture in this tract, but there are also coconut and arecanut (also known as betelnut) orchards. A special variety of paddy is cultivated in the brackish waters in the estuaries, a form of cultivation requiring little labor beyond broadcasting seed and harvesting grain. The arecanut orchards in the hills are multistoried plantations with pepper vines trained onto the arecanut trees and bananas - constituting a middle canopy; cardamom forms the ground layer. Only occasionally are hill slopes cultivated, and then usually with millet species such as Eleusine coracana. The leached soils in this region of high rainfall are nutrient poor, and there is a tradition of adding substantial quantities of organic manure in paddy fields as well as in orchards. This manure consists of loppings of leaves from forest shrubs and trees and dung of domestic livestock. The only cultivated lands to which no such manure is applied are the estuarine lands; the river silt yearly deposited on such lands is rich in nutrients.

Animal Husbandry

A few chickens are maintained by all meat-eating communities of the tract. All of the farmers maintain a few cattle and often buffalos. These largely serve to convert grass on which they graze into dung, used as organic manure. The production of milk is quite low. There is also little demand for animal power in paddy cultivation and coconut and arecanut orchards, nor is there much use of bullock carts for transport due to the hilly nature of the terrain. Only in recent years has goat keeping been introduced to this tract. Havugalla, a nomadic community, uses donkeys as beasts of burden, and in earlier days, some horses were used for transport.

Human communities

Endogamous Caste Groups

As in much of India, the society consists of a large number of endogamous caste groups. Members of any caste group almost always marry within their own caste. Outside their caste group they have considerable economic interaction but little social intercourse. Each caste has its own leadership that resolves many of its internal conflicts and regulates its behavior. Each caste has customarily been assigned a position in the social hierarchy, and based on such position the castes have been divided into five varnas: Brahmins, or priests; Kshatriyas, or warriors; Vaisyas, or traders and artisans; Shudras, or peasants; and Panchamas, or untouchables. These varnas are, however, an artificial construct, the genetic affinity generally being stronger among different caste groups in the same locality, regardless of varna affiliation, than among different caste groups assigned to the same varna. There is also little social intercourse among different endogamous groups within the same varna, this being strong only within a given endogamous group. The existence of these castes is not restricted to those belonging to the Hindu religion; the caste system has been retained by those converted to Islam and Christianity as well (Karve, 1961).

Each sedentary caste group has its own compact settlement; a village is thus a collection of several caste-based settlements, or clans. Any village community is then made up of one or more clans. Members of a given clan have great commonality in their pattern of resource use; traditionally, they even cultivated land communally or participated in communal hunts. However, different clans within a given village community may differ markedly in their pattern of resource use. The sedentary clans would further differ markedly in their pattern of nomadic endogamous caste groups in their resource use patterns.

Our estimate is that around 30 sedentary and 20 nomadic endogamous groups occupy the region of 2,000 km² of interest to us. It is sufficient for our purpose, however, to consider nine of these groups - one nomadic and eight sedentary. Of these, Havugallas are nomadic hunter-gatherers, Ambigas are fishermen, Halakkis have a broad subsistence pattern including farming, Patagars and Naiks are farmers, Haviks are a priestly caste primarily devoted to horticulture, Saraswats are a priestly caste involved in trading, Moslem traders are a group engaged in maritime trade, and Acharis are carpenters (Campbell, 1883).

Havugallas

Havugallas are nomadic people who travel in small bands of one or two nuclear families accompanied by dogs and donkeys. They camp well outside of villages for a few days at a time, hunting many animals including snakes and monkeys that are taboo to all other communities of the area.

Ambigas

Ambigas have their settlements on estuaries and the sea coast and own no land or livestock. They fish with nets in open waters with the help of small boats.

Halakkis

Halakkis have the broadest subsistence pattern of all communities. They hunt avidly for game birds, hare, and deer; they extensively collect bivalves and oysters from the rivers and trap fish by using tidal flow; they cultivate paddy in monsoon and vegetables in the summer; and they weave mats from leaves of Pandanus. They maintain a small number of cattle and undertake small-scale construction work. Their settlements are restricted to the coastal tract.

Patagars

Patagars are restricted to the sides of the rivers on the coast and are engaged in cultivating paddy on uplands as well as in the brackish waters of estuaries. They maintain a good number of cattle. They also weave mats from Cyperus reeds.

Naiks

Naiks are largely restricted to broader upland valleys where they practice paddy cultivation. They maintain a good number of cattle and indulge in hunting game birds and larger mammals.

Haviks

Haviks are a priestly caste supposedly brought to the region in medieval times to transfer worship of the temple at Gokarna away from a nonpriestly group. Many families are still priests with little land holdings; others have raised arecanut orchards on the coast as well as in the valleys up the hills. They maintain large numbers of cattle and consume milk products extensively. They are strict vegetarians and traditionally do not hunt or fish at all.

Saraswats

Saraswats are a priestly caste widely distributed on the coast and on the hills engaged in trade and moneylending. Under British rule they came to own extensive lands. Unlike Haviks, they did not cultivate land themselves but let it out to the tenants. Saraswats are among the few priestly castes that consume fish and shellfish; traditionally, they do not eat any other meat.

Moslem Traders

Moslem traders are descendants of mixed marriages between Arab traders and locals who do not practice cultivation or animal husbandry but who specialize in maritime and other trade. They consume both fish and meat.

Acharis

Acharis are carpenters who traditionally worked for an inherited clientele in one or more villages on a jajmoni basis. That is, they were paid in kind a certain proportion of the other families' produce every year for looking after those families' needs for carpentry. They do not cultivate or keep animals. They eat fish and meat.

Traditional patterns of resource management

The System

In the pre-Colonial period, Indian society had evolved an interesting pattern to regulate competition over resources. The villages were made up of populations of several endogamous caste groups knit together in a web of mutual dependency. Each caste group had a specific, hereditary, and often exclusive function assigned to it. Thus, any given Achari household had the exclusive responsibility for carpentry operations for certain village households, or a given

Ambiga household for supply of fish to certain other village households. In turn, farming households provided a defined proportion of their farm produce to the Achari or Ambiga households who served them. The village community as a whole also provided a portion of their produce to the king as tax.

The cultivated land was often owned communally by each clan - all households of a given caste group in the village. The king, in theory, owned all uncultivated lands and waters and had the right to assign a portion of it for cultivation. The village community, however, effectively controlled all these resources, which were partitioned in a way that assigned monopoly rights over certain resources to a particular clan. Thus, only Halakkis collected bivalves and only Ambigas fished open waters. There were further regulations in the use of resources such as timber or fuelwood that were required by all clans of the village and gathered from uncultivated lands controlled by the village community as a whole.

This was, then, a system producing only low levels of surplus for the ruling elite and with extensive communal management of resources based on socially accepted customs and conventions. It probably permitted sustainable use of the resource base that served a village community (Gadgil and Malhotra, 1983; Gadgil, 1985).

Colonial period

The Colonial System

In establishing their hold over India, the British sought to convert the prevalent pattern of resource use (that generated little surplus for the state and was based on strong communal regulation) into a pattern that would generate higher levels of surplus for the state with resources under its firm control. By the time of conquest, the British society had rejected communal and customary modes of resource control. The British rulers imposed this system in India, insisting that the only legitimate forms of resource control were through individual and state ownership, and that all resource use should be fully codified. All cultivated land was therefore to be individually owned, with the owners responsible for paying a certain level of taxation in cash. All other land and waters were to be state property, and to be utilized as far as possible for generating resources of value to the British economy. In this hilly and forested district with excellent natural growth of teak in the moist, deciduous forest zone, the attempt was to convert as much of the uncultivated land as possible into state-owned teak plantations. A certain amount of uncultivated land was permitted, however, to generate resources for the local population, although its ownership and ultimate control was firmly vested in the state authority (Gadgil et al., 1983).

The principal consequence of this policy was near total loss of control over resources by the nonliterate communities such as Halakkis, Patagars, and Naiks. With the insistence on individual ownership of land and payment of taxes in cash, these communities quickly ran into debt and lost the ownership of land to the two literate, priestly castes, Saraswats and Haviks, who could adapt to the new system of codified control of resources. While a certain amount of resources of uncultivated land continued to be available to the local population, this was as a privilege; their management rights were removed. Good communal management of these resources, therefore, began to break down, especially as the population began to increase with control of epidemic diseases. The result was the unsustainable utilization of resources and their decimation. There was little possibility at this stage of generating any surplus from aquatic resources, which were left alone. However, there was siltation and shallowing of the west coast rivers, which may have affected the aquatic life.

Reserved Forests

About half the uncultivated land of the region, amounting to 40 percent of the total land, was constituted into reserved forests under full control of the state. The British were primarily interested in the production of teak from these forests, and extensive tracts, especially in the moist, deciduous forest zone, were converted to teak plantations under protest from local populations, who valued the natural mixed forests (Dhareshwar, 1941). The local people retained certain privileges of use of even the reserved forests, including grazing in natural forests and older plantations and collection of dead and fallen wood, generally under payment of some charge. Hunting was continued, and elephants became part of the game. With the introduction of firearms, many of the British and Indian government officials became avid hunters. Another interesting development was that some of the Saraswat and Havik landowners, albeit belonging to priestly castes, also took to hunting with the help of firearms.

Sacred Groves

The sacred groves were strictly protected patches of forests that were only occasionally utilized in times of distress. Consequently, they had some of the beat preserved natural vegetation. The British attitude towards these groves is well expressed in the following quotation from Buchanan, one of the earliest British chroniclers of Peninsular India:

The forests are the property of the gods of the villages in which they are situated, and the trees ought not to be cut without having obtained leave from the . . . priest to the temple of the village god. The idol receives nothing for granting this permission; but the neglect of the ceremony of asking his leave brings vengeance on the guilty person. This seems, therefore, merely a contrivance to prevent the government from claiming the property. (Buchanan 1802; reprinted 1956).

All the groves on communal land were taken by the state as reserved forests, leaving those in the midst of cultivated land under private control. In this tract, the sacred groves taken over were constituted as so-called "green forests" from which people were authorized to remove only dead and fallen wood. These groves retained well-preserved tree cover throughout the colonial period.

Minor Forest

Roughly half the uncultivated land was put under the control of the land revenue authorities of the government and constituted either as minor forest or as leaf manure forest land. The entire local community had full access to the minor forest land for meeting their fuelwood, grazing, and leaf manure requirements without payment of any charges. This right included the cutting of live wood. With no communal management, the minor forests were overutilized and depleted in many areas.

Panchayat Forests

A few pockets of minor forest land continued under the control of local communities, which constituted a council or panchayat for their management. With continuing control by village communities, many such panchayat forests were managed in a sustainable fashion and retained good forest stock throughout the British period.

Leaf Manure Forests

In the pre-British period, the arecanut orchard owners claimed rights, either individually or as a clan, over forest tracts immediately adjacent to their orchards. This right of ownership was not conceded by the British government, and this land was taken over as land under ownership of land revenue authorities. Nevertheless, the orchard owners were conceded extensive privileges of free grazing and fuel and leaf manure collection from these lands. They were also permitted to extract some timber from the leaf manure land on payment of charges provided that a minimum density of 100 trees per hectare was maintained.

After independence

The New System

There had been a vigorous debate during the independence struggle over the kind of society and economy that the country should strive for on achieving independence. Mahatma Gandhi had advocated the restoration of a self-reliant and largely self-sufficient village economy. This would have implied strong communal control over the common property resources. Mahatma Gandhi was also against industrialization on the western model. On the other hand, Jawaharlal Nehru, the first prime minister of independent India, favored vigorous pursuit of modernization and industrialization. He also favored centralized planning on the Soviet model, albeit in the context of a mixed economy. Nehru's point of view largely carried the day, especially as it coincided with the interests of the business and the urban literate classes who have dominated the policies since independence. As implemented, this policy has resulted in state sponsorship of heavy industry and power and irrigation projects, leaving other sectors largely in private hands. Resources were made available to the private and public industrial sector at highly subsidized rates to promote their growth. Forest-based industry thus was assured a supply of forest raw materials on a long-term basis at throwaway prices. These policies meant that demands on the resources of the uncultivated lands and waters of the country were substantially stepped up. This generated pressures for further alienation of the local rural population from access to these resources. For instance, there were moves to take over minor forests to raise industrial plantations, and many rivers have been converted into dumps for chemical wastes instead of sites of fish production.

At the same time, there have been measures to win over the rural population-the major voting blocks. The agriculturists have been provided irrigation and fertilizers at highly subsidized prices, and ownership of land has been largely restored to the cultivators, certainly in the Bedthi-Aghanashini region. However, the initial attempts to restore communal organization and management of resources (such as community development programs) have been declared failures and abandoned. The cooperative movement in the rural areas has also been discredited. Thus, the new organizations of urban literate classes and the business community and the bureaucracy and business corporations have grown stronger, while those of the rural masses have little clout left. This has enabled the industry and the bureaucracy that shares its interests to divert the resources of the uncultivated lands and waters to its own ends. The bulk of the rural population is, however, quite dissatisfied with this situation, and hence unwilling to cooperate in good management of resources towards this new objective. The result has been further rapid degradation of the common property resource base since independence (Gadgil and Malhotra 1985; Centre for Science and Environment, 1985).

Aquatic Resources

The Aghanashini remains one of the few unpolluted rivers of India, and its estuary is still productive of fish and shellfish, which are harvested by Ambigas and Halakkis. However, a significant new element has been added in the form of development of fish and prawn cold storage and canning facilities coupled to the export of prawns. This has considerably raised the value, especially of bigger prawns, and has generated a vigorous commercial market. The two trading castes of the region, Saraswats and Moslem traders, have taken advantage of these new developments, and become active in both trade and processing.

Uncultivated Lands

The level of harvest from these lands has been substantially stepped up to meet the escalating needs of both industry and the increasing rural population. The result of this nonsustainable use has been a rapid decline in the plant biomass cover of such lands. The reserved forests, sacred groves, minor forests, panchayat forests, and leaf manure forests have all undergone such depletion to varying extents. In reserved forests, there has been an accelerating pace of clear felling of natural plantations for raising not only teak, but Eucalyptus plantations as well. There has been vociferous protest against Eucalyptus plantations from farmers who believe that the runoff from these plantations affects their crop yields. The local taboos against the violation of sacred groves have rapidly disappeared since independence, resulting in accelerating exploitation of many of them. Minor forests have suffered most severely with unchecked fellings by local communities and many others. In Masur, one of the villages where we have been working, for instance, the local leaders of the Patagar and Halakki communities did make an attempt to impose some social restraint on fellings from minor forests, but were rebuffed by their own women.

Panchayat and leaf manure forests are two categories of forests with some continuing tradition of management by local communities, clans, or individual households. Many of these, too, have been overexploited, although others are well managed and retain good plant cover. However, bureaucracy has attempted to take over many of these, and the resulting uncertain atmosphere has led to indiscriminate fellings in many panchayat and leaf manure forests. For instance, there are two panchayat forests close to the town of Kumta. The government served notice on both for takeover as reserve forest. One of the panchayats has contested this in court; this forest is still fairly intact. The other panchayat agreed to the takeover; within a few months, the forest had been totally destroyed by the local residents.

Recent trends

The System

The pace of nonsustainable utilization and consequent degradation of the resource base of waters and uncultivated land has by now reached a magnitude serious enought to compel response from all segments of the society. The response of the Ambigas, Halakkis, Patagars, Naiks, and Havugallas, the still largely illiterate communities being further and further impoverished has been to abandon whatever traditions of social restraints on overuse of resources that they still retain. The business communities have continued to prosper in the process of liquidation of the capital of the natural resource base, and their response has been a defense of the existing system. The urban literate classes in the professions and bureaucracy are, however, beginning to question the existing system and propound the need for a new order that lead to sustainable resource use. Wherever there is an element of such a literate class in the rural population, they, too, have called for new initiatives. Three such responses are worth further consideration here.

Forestry Sector

The forestry system has so far been dedicated to eliminating all privileges enjoyed by the rural population and to serving the interests of the urban-industrial sector. A significant minority, however, is questioning this approach and attempting to inject new ways of managing the uncultivated lands to generate resources for the rural population. This has led to the development of the so-called social forestry programs and, very recently, the establishment of a national wasteland development board, which, in turn, has led to the afforestation, for the first time, of minor forest lands in the BedthiAghanashini valleys, beginning in 1984. This afforestation has been supported by some of the more properous and literate Havik farmers, but many others have opposed it. Nevertheless, there is growing acceptance of such programs both within the forestry establishment and by the local population. Another remarkable innovation of the foresters has been the planting of several new "sacred groves" near major temples of the Bedthi-Aghanashini valleys.

Appiko Agitation

Some of the younger Havik farmers have organized a campaign against the policies of the forest department, deriving inspiration from the leadership of Sunderlal Bahuguna of the Chipko agitation in the Himalayas (Centre for Science and Environment, 1985). They have called for a complete cessation of all felling in reserve forests. The forest bureaucracy has responded by attempting to drive a wedge between the literate, priestly caste of Haviks and the illiterate, poorer castes, such as Naiks, by pointing to the extraordinary privileges of leaf manure forests enjoyed by the Haviks alone. The agitation has enjoyed a few successes in fits and starts - some fellings have been stopped - but has not acquired any broader support.

Ecodevelopment Movement

Some of the other younger Havik farmers seriously committed to bringing in new technologies to their calling have taken a managerial approach. They have insisted on better management of all uncultivated land, including the leaf manure forests, under their own control. They have joined with elements from scientific and technical communities, including this author, to promote more careful harvest from leaf manure forests, control of grazing, replanting of the degraded leaf manure and minor forest lands, and so on. Initially, this movement startedexclusively with the more properous Havik farmers. However, realizing the importance of broadening the base of the movement, it is now actively attempting to include Halakkis, Patgars, Naiks, and others in its fold (Prasad et al., 1985).

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Kenya: Seeking remedies for desert encroachment

H. F. LAMPREY

Introduction

The immediate causes of desertification in the arid zone of northeast Africa and the Sahel are overgrazing and woodland felling. A number of underlying, indirect causes, however, result from the difficulties of reconciling traditional nomadic pastoralism with modern influences, and the expanding human and livestock populations. The author, formerly the project coordinator for the Integrated Project in Arid Lands (IPAL) program of research in northern Kenya - a regional project intended to obtain results widely applicable in the African arid zone - is attempting to solve some of the ecological and socioeconomic problems associated with desert encroachment.

The IPAL program was established as a pilot operation to initiate research into the causes and effects of desert encroachment in a subdesert region: one inhabited by nomadic pastoralists, where a money economy has yet to replace the ancient livestock economy. The main purpose of the project is scientific inquiry by a multidisciplinary team into the deleterious changes taking place in this arid-zone ecosystem. There is also an important second objective - that of seeking practical modifications and alternatives to the traditional livestock-based economy, which might enable the degraded grazing lands to be rehabilitated.

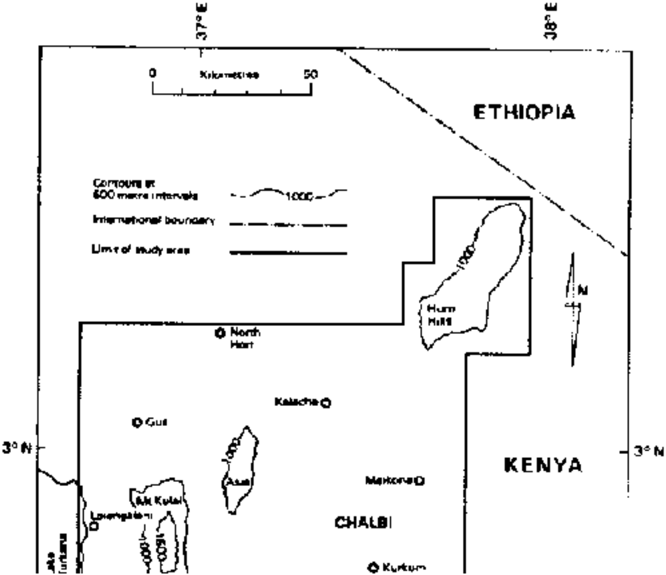
The broad scope of the problems associated with desert encroachment and its control has become increasingly apparent to the scientists engaged in the project during the last few years. Overgrazing and excessive tree felling are the most immediate and obvious causes of desertification in northeastern Africa, but the degradation of enormous areas of grazing land and woodland in dry tropical Africa can also be attributed to the underlying administrative and socioeconomic factors associated with such regions of low economic potential. Some of these factors are shown diagrammatically in figure 8-1.

Field work started in 1976, and has been carried out mainly in the subdesert country of northern Kenya, between Lake Turkana (Rudolf) in the west and Mount Marsabit in the east (figure 8-2), a study area of 22,500 km² mostly about 500 m above sea level; preparatory reconnaissances have been made in Sudan and Tunisia. In Tunisia, another program of arid-zone research, following the IPAL pattern, has recently been started by UNESCO.

Background

More than half the land surface of Kenya is arid or semiarid rangeland occupied by traditionally nomadic pastoralists of several tribal groups. Like tribes living elsewhere in northeastern Africa and the Sahelian zone, they subsist almost entirely upon their herds. But unlike the greater part of the Sahel, there is virtually no arid-zone agriculture in Kenya, and consequently there is little of the interdependence between agriculturists and pastoralists that is characteristic of the Sahelian zone. The small amount of grain food consumed by the pastoralists in northern Kenya is brought into the region from outside.

The overwhelming problem of the arid regions of northeastern Africa and the Sahel alike is the apparent incapacity of the land to support, on a sustained-yield basis, the numbers of domestic animals owned by the pastoralists and, in many cases, needed for their subsistence. Overexploitation - first of the grasses and other vegetation, followed by the trees and shrubs - with concurrent soil erosion, compaction, and dessication, is causing a decline towards desert conditions over large areas. The result is a reduction in the capacity of the land to support the numbers of people who occupy it. The problem is aggravated by population growth, which in northern Kenya is running at 2 percent.



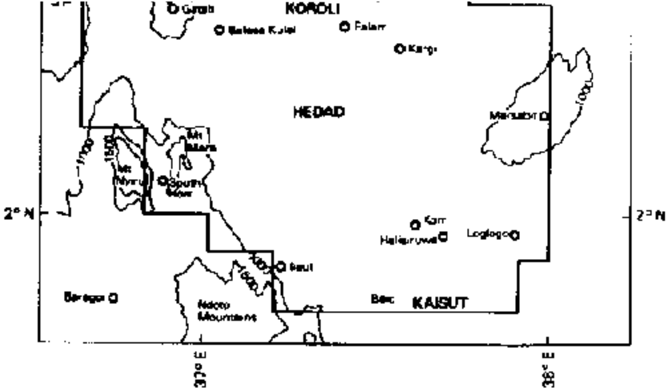
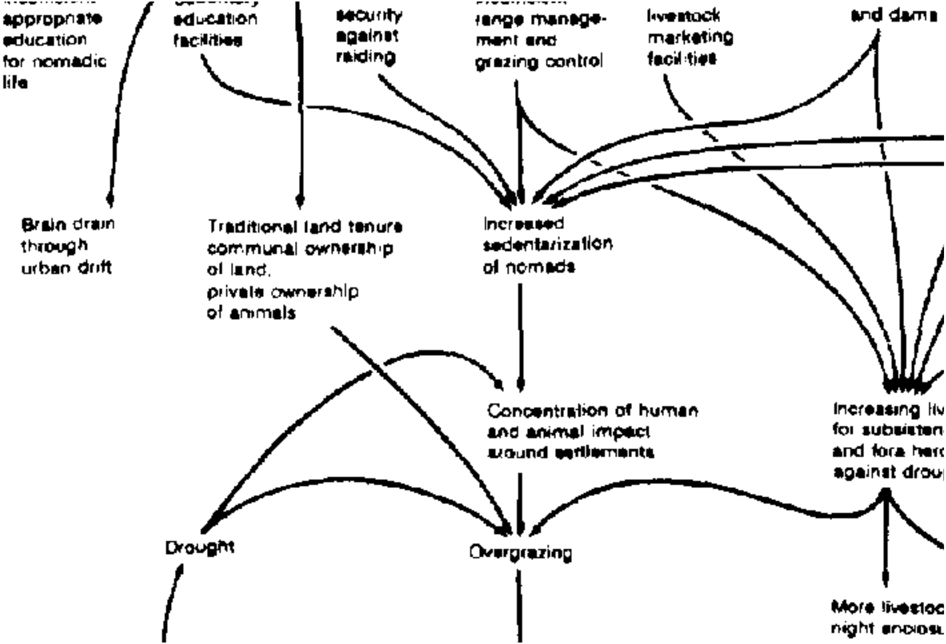


FIGURE 8-1 Area in northern Kenya of the IPAL study.



appropriate
education
for nomadic
life
education
facilities
security
against
raiding
range manage-
ment and
grazing control
livestock
marketing
facilities
and dams
Brain drain
through
urban drift
Traditional land tenure
communal ownership
of land,
private ownership
of animals
Increased
sedentarization
of nomads
Concentration of human
and animal impact
around settlements
Drought
Overgrazing

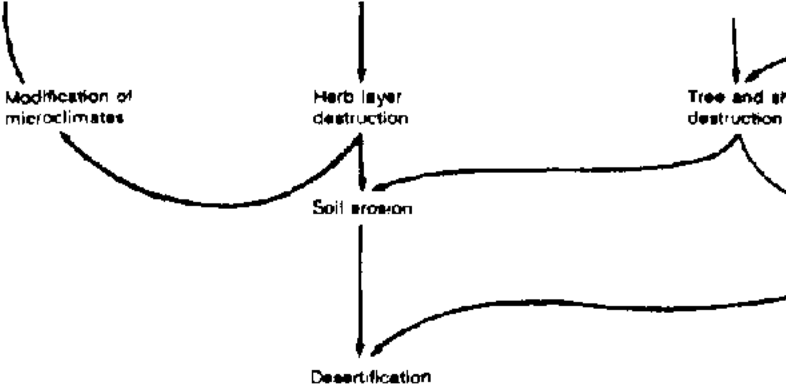


FIGURE 8-2 Some of the factors causing desert encroachment in northern Kenya. (Reproduced from Nature and. Resources, 14,4,1978)

Water Supplies

The main cause of the degradation is the new trend towards settlement in the traditionally nomadic tribes. Centers of human and livestock concentration have arisen and have expanded rapidly around the few springs and wells, but especially near recently installed boreholes. Although fresh water is the main attraction for such concentrations, shops, schools, medical centers, and famine relief centers are additional incentives to settle.

Of equal importance is the protection that the villages, many with small police posts, offer against intertribal raiding. Lack of security over large tracts of land is a major reason for avoiding them and for the gross overexploitation of the more secure areas. Each concentration area becomes a nucleus of denuded land, from which the degradation spreads in widening circles' as the people are obliged to go further for grazing and for the wood they need for both fuel and livestock fencing. Localized desertification appears to be gaining pace as a growing proportion of the pastoral population becomes settled.

In each dry season, and also through more prolonged droughts, such as that of 1968 to 1976, there is an almost total dependence upon the few perennial water supplies, and the destructive effects of the concentration are most marked. During and immediately after the rains, the traditional dispersal of nomadic families takes place as they move into areas where rain has fallen and new growth has appeared.

This dispersal still occurs, although on a much reduced scale, and an increasing proportion of the population, especially the women and children and the older men, remains close to the villages, keeping their milch animals with them. The young men continue to move out into the surrounding country, taking the unproductive animals (known as the fore herds), males, castrates, and barren females, following traditional nomadic practices.

Fora Herds

The fore herds serve as insurance against drought and other misfortunes, including theft and death from disease. In favorable years, they may appear to be a large surplus stock of unproductive animals that contribute to the depletion of the vegetation. It is questionable, however, whether their reduction would significantly lessen the rate of desert encroachment, for they are mobile and widely dispersed and appear to have relatively little impact on the vegetation.

Excessive Stocking Rate

Among the inescapable constraints to the management and the desired diversification of land use in this region is the dry and variable climate. With a mean annual rainfall of less than 150 mm, sustained agriculture is not possible over the greater part of the region; animal husbandry will inevitably remain the basis for the economy. In a purely pastoral society, in which a minimal subsistence herd for a group of six to eight people is about 50 cattle (or their productive equivalent in sheep and goats or camels), it can be calculated that about 1,200 kg liveweight of domestic stock (5 cattle, 2.5 camels, or 25 sheep and goats) is necessary to supply one person.

The project study area contains some 30,000 people who are supported by about 36,000,000 kg liveweight of domestic stock. Although this implies a stocking level barely sufficient for the subsistence of the human population, it is evident that, under current pastoral regimes - and more particularly in view of the increasing tendency of traditional nomads to settle - the long-term carrying capacity of large areas of savanna rangeland is being greatly exceeded.

During years of favorable rainfall (as in 1977 and 1978), there may be a temporary abundance of animal fodder, with a resulting increase in the herds. This leads to overstocking in subsequent dry years when plant production is greatly reduced. Prolonged drought inevitably causes high mortality in the herds, but by the time this happens considerable damage will have been done to the vegetation.

Traditional pastoralism

No system yet exists in the region for the management of grazing. Traditional land tenure among pastoral tribes ensures communal ownership of the grazing resources within each tribal area, although there is individual ownership of livestock. It is not surprising, therefore, that nobody takes responsibility for the maintenance of the pastures and the uncontrolled competition for the limited grazing.

Although many pastoralists see the need to reduce stocking rates, substantial culling of their herds is very unlikely for several reasons. Under their existing economy, the majority of the families are already at or near the subsistence level and cannot afford to reduce their herds. The more prosperous families are reluctant to reduce their stock, which represents not only their livelihood, but capital, insurance, and prestige as well. And in this region the prices offered to the pastoralists are commonly too low to persuade them to sell many animals during times of abundance.

Despite the clear disadvantage in the present livestock economy, the traditional animal husbandry practiced by the Gabra and Rendille pastoralists of northern Kenya is, in most respects, efficient and well adapted to the harsh and variable climate and to the subdesert conditions. In any attempt to rationalize land use in the region, traditional practices and skills should not be discouraged, except where they are shown to contribute to environmental damage.

Drought periodically causes famine after a large number of animals have died. With the return of favorable conditions, many families have been left without livestock and have become destitute, dependent upon the continued supply of famine-relief food. Such people tend to increase the unproductive sedentary populations and appear to lose their will to return to a nomadic life.

Baseline studies

It is against this background of socioeconomic difficulties that IPAL is looking for the means to achieve ecological and social rehabilitation. There can be little doubt that far-reaching changes in land-use policy will be necessary. Range management alone will necessitate a degree of control that may fail if it is not supported by the willing involvement of the pastoralists. The project's approach to impending land reform, designed to arrest desert encroachment, has been to gain the support of the people through public relations activities.

The first task of the project has been to make an inventory of basic information on the climate, soils, water distribution, vegetation, wildlife, and domestic livestock, and on human populations and their economic, social, and cultural characteristics. Vegetation and soil maps have been prepared; a preliminary analysis of the climate has been made on the basis of past records from the region; and meteorological observations from a network of stations and rain gauges have been set up for the project. In addition to its aridity, the most important feature of the climate is its variability: between 1968 and 1980, the annual rainfall has ranged from 50 mm to nearly 400 mm in the subdesert areas.

Vegetation and livestock

The main focus of the research program is the interaction between the pastoralists and their livestock on the one hand, and the vegetation on the other. The capacity of the pastures and woodlands to support livestock depends on the sustainable production of the vegetation. Plant production is closely correlated with rainfall, and the fluctuating climate results in highly variable production from year to year and, due to spatial irregularity as well, to localized variation.

Primary production is measured by the systematic sample clipping of herb and dwarf shrub vegetation, to simulate grazing and browsing. Basic production is expressed as dry weight per unit area and is related to recent rainfall and to other characteristics of the site, including topography, drainage, soil type, and history of use. The measurement of tree and shrub production is considerably more difficult but will be undertaken as well.

Livestock food preferences and food-intake measurements have been obtained in fenced plots where the stocking rates of camels, sheep, and goats could be controlled. By simulating various livestock densities, the effects of grazing at different intensities could be observed, and it was possible to make preliminary estimates of the short-term impact and the carrying capacity of the vegetation type being studied, and under the prevailing climatic conditions.

In the region as a whole, livestock numbers and distribution have been assessed periodically from the air. Ten surveys carried out in both the dry and the wet seasons have shown that at least 20 percent of the study area is heavily overstocked when judged by widely accepted range management standards, and from the results of the project's stocking trials. As would be expected, the overstocked areas are those surrounding the settlements, but they frequently extend out from village centers as much as 30 km and can only be described as deserts.

In close association with the studies on plant productivity and the impact of animals, the project is studying several aspects of the ecology and management of livestock, with the objective of understanding the quantitative relationships of the herds both with their food resources and with the human populations that depend on them. Useful results have been obtained on the productivity of camel, sheep, goat, and cattle populations..including population dynamics, growth and weight gain, milk production, and potential for meat production. Diet and water intake in relation to seasonal changes and availability are being studied.

It is evident from this experience with experimental herds that animal production is markedly affected by disease and parasites. Preliminary disease.control trials have shown that, despite the generally high levels of resistance in indigenous livestock, growth rates and milk production are greatly improved by minimal treatment for a small number of diseases. This holds out hope that badly needed increases in animal production might be achieved economically without further increase in animal numbers.

Directions for the future

When IPAL eventually makes recommendations on livestock and range management methods that will be consistent with the rehabilitation of the vegetation, it seems probable that the management guidelines will be based very largely on rational modifications to the traditional methods of animal husbandry now practiced by the nomadic pastoralists.

Before any attempt can be made to plan such modifications (possibly including improved breeding, the introduction of controlled grazing, the controlled use of available water, obligatory selective culling of herds, and the introduction of animal product marketing), it is essential to gain an understanding of the traditional animal husbandry regimes in the region. For this reason, an important component of the project is a study of traditional livestock management methods and their relevance to modern techniques, designed to optimize both the productivity and the conservation of the rangelands.

The hema system in the Arabian peninsula

BY OMAR DRAZ

The Arabian hema (plural ahmia) grazing system, one of the world's oldest effective range-conservation systems, can be used by individuals, tribes, or governments. A survey in Saudia Arabia (19621966) of historic ahmia, such as Hema Hail, Hema al Hourma, and Hema al-Ra'bza (rainfall under 150 mm), which were formerly administered by the government, showed that these lands were opened to free grazing by decree in 1953. Today it is difficult to see any difference between the vegetation on these government reserves and adjoining lands because of the effects of destructive grazing and the uncontrolled cutting of trees and shrubs. By contrast, tribal or personal ahmias that had been properly managed retained satisfactory levels of productivity, underscoring the suitability of this system within the context of the local environment.

AHMIA IN ISLAM

The Prophet Muhammad was concerned with fodder reserves because they preserved the strength of the Islamic nation. He protected Hema Alnaquia (a wadi near Medina that was used mainly by animals) to defend the cause of Islam, and is known to have said: "Hema is only for God and His Prophet." Evidently this has been interpreted to mean that a governor or an Islamic state is allowed to protect the ahmia in the best interests of the community.

Al-Iman al-Shafi'y (ninth century) stated that during pre-Islamic days, a Sharaf-al-koom (influential person), upon arriving in a village, would mark the boundary of his grazing land by the distance one could hear a dog bark. In addition to this area for his personal use, he also enjoyed the privilege of the surrounding lands grazed by others.

This extremely unfair practice, according to al-Imam al-Shafi'y, was the system practiced by the Jahilia (pre-Islamic or unenlightened people). It was subsequently corrected in accordance with the saying of the prophet, "Muslim people are partners in water, fire, and ephemeral range."

The Hema al-Ra'bza, near Dari'ya in Saudi Arabia, is the pasture preserve once protected by 'Umar ibnal-Khattab, the second caliph. The length of the hema was about 250 km. A geographic Arabic dictionary, Mo'gam ma ista'gam, revealed that during the time of 'Uthman, the third caliph, this hema was expanded and the number of grazing animals (mainly camels and horses) increased to 40,000.

'Umar ibn 'abd Aziz (seventh century), one of the most capable caliphs of the early days of Islam, is known to have been very strict in keeping the hema protected. Cutting of even a single branch from such a reserve warranted a severe beating.

The Holy Qur'an is a proponent of conservation and forbids the unnecessary cutting down of trees, destruction of crops, or any wanton destruction whatsoever in war or in peace. Both law and the Islamic concept are opposed to such destruction.

Types of Ahmia

The ahmia may be classified according to the type of protection:

. Animal grazing is prohibited, but cutting of grasses is permissible during specified periods and droughts. The head of the tribe grants special privileges for a limited number of needy people to use the reserved range. A specified member of each family is allowed to cut mature grass during the season, either for storage or for direct use.
· Grazing, cutting, or both are permitted but are restricted to certain seasons of the year, as in Hema Elazahra and Hema Hameed around Belgurashi in Saudi Arabia.
· Grazing is allowed year-round. The kind and number of animals

permitted for grazing are specified. Most of the ahmia around Taif are in this category, and grazing is restricted to cattle and donkeys. There is, however, no restriction on hay cutting after grass matures.

· The reserve is kept for beekeeping. The number of these ahmia is limited, and grazing restrictions are relaxed after the flowering season.

· The reserve aims to protect forest trees such as juniper, acacia, and ghada (Haloxylon persicum). These ahmia are usually the common property of a village or a tribe. Cutting of trees is prohibited except in cases of dire emergency or need, such as rebuilding a house destroyed by a calamity, or for building a mosque or school. Sometimes the wood is sold to raise funds for the benefit of the village or tribe.

Some ahmia are reserved for a particular tribe or for one or more villages. The tribal or village head manages the use of such reserves. However, comparatively smaller units are kept close to terraces or cultivated wadi beds for the use of local residents.

Rights of ownership or use

Rights of ownership or use are determined as follows:

· Those who possess documentary evidence of hereditary ownership of rights of use; or
· Those without documentary evidence, but who maintain control of ahmia because of long-term possession and use.
Such rights are maintained through the local tradition, ourf.

Trespassers are penalized by chiefs of tribes or villages. A person committing an offense for the first time usually pays a fine of a sheep or its equivalent. The fine, in certain cases, contributes to the welfare of the tribe or community, instead of being paid to the owner of the hema. Some difficulty is experienced in Saudi Arabia in protecting the hema because many people misunderstand the 1953 decree as allowing free grazing.

During a drought year, when fodder is scarce, a calamity-stricken tribe may request permission to graze animals on the hema. The owner of the hema generally permits grazing, but places a limit on the number of animals and specifies the period of grazing. This restriction is a protection against overgrazing.

The hema system in Saudi Arabia

Ahmia in the Taif area of Saudi Arabia were studied to determine the boundaries, location, method of upkeep, ownership, grazing rights, and the presence of old water and soil conservation works. A total of 30 ahmia were located, and investigation showed that 18 were well looked after and kept under proper controls, while 12 were open to unrestricted grazing. The Hema Banu Sarr in the Hijaz mountains was selected for a special study.

The range has long been protected, and its history can be traced back some 500 years to the reign of Sharaf Husayn of Makkah (Mecca). Two tribes, Banu Sarr and Banu Hassan, quarreled over its control, but Sharaf Heidera, a judge of Sharaf Husayn's reign, gave his verdict in favor of Banu Sarr and conferred upon this tribe the rights of custody and use. The Hema Banu Sarr has been protected since that time.

This pasture, with total surface area of about 800-1,200 hectares, is located north of Belgurashi at about 2,000 m above sea level. Yearly average rainfall is between 400 and 500 mm. Soil profiles observed along road cuts showed substantial accumulations of good soil under the grass cover. This soil has retained its fertility and has the capacity to produce abundant forage.

Increased growth of choice grazing plants has reduced the growth of undesirable vegetation, and highproductivity grasses now dominate the landscape. The grass cover is composed mainly of genera such as Themeda, Aristida, Andropogon, and Stipa. Localized patches of Cymbopogon and Polypala were also found, together with some Olea chrysophylla and Juniperus procera. The plant cover of the areas outside the hema is composed of heavily grazed grasses and large numbers of nonpalatable shrubs. Dodonea viscosa, Olea chrysophylla, and Juniperus procera are also present in fair number.

The right of use of this hema is strictly limited to the Banu Sarr tribesmen. No year-long grazing is allowed, but cutting of grasses is permissible during periods of scarcity or late in the summer season when the grass is mature. Permits for cutting or collecting grass are granted by the tribal head. No more than a specified number of persons of each family is allowed to cut mature grass, and then only on certain days of the week.

Although no reliable data is available on the number of animals for which this range is kept as a reserve, it is evident that an equilibrium between vegetation and animals has always been maintained. The perennial vegetative cover of palatable grasses within the hema, as compared with the surrounding areas, could support this assumption.

Hema Hureimla, 80 km north of Ar Riyad (Riyadh), with less than 80 mm of rainfall, is another good example of the effect of protection and conservation on the regeneration of plant cover. Comparison of the protected parts of wadi against the nonprotected parts shows a contrast; 1 have counted 28,000 acacias in an area 4 x 1 km along the protected area, compared with none along the upper or lower parts of the same wadi. A small dike outside the hema did not have any appreciable effect on the perennial vegetative cover compared with that growing under hema protection.

Hema Oneiza, in the heart of Najd plateaus, has the unique objective of protecting Haloxylon persicum trees for effective stabilization of moving sand dunes adjacent to Oneiza along a 70 x 40 km area.

Ghidal is another type of hema once common in Maghreb, Algeria, and Tunisia. Only a few examples are left in these countries.

The total number of existing ahmia in Saudi Arabia has recently been reported to be at least 3,000.

The mahmia or marah, and the koze system in Syria

A reference to hema practiced in the Sweida mohafazat rangelands is made by Shibly al-Aisamy and coworkers (1962) who, while describing the troubles that occurred late in the 19th century, reported the following:

[T]he harsh injustice, which had been described clearly and in detail by the folkcloric poet (Shibley ElAtrash), created a new widescale revolution in 1897. Among the direct reasons mentioned for this revolution was that one of the guards of the hema of Urman (close to El-Qraye, rainfall about 300 mm) quarreled with a bedouin who trespassed this hema. Upon the complaint made by the bedouin to Mandouh Parsha (the military governor) in Sweida, 30 soldiers were sent to Umran [sic] under the pretext of arresting the guards and punishing them; yet the real reason had been to arrest representatives of this village who previously met secretly with representatives of neighboring villages to protest the Turks' injustice....

The previous presence of hema in this region has also been confirmed by several old shaiks of the Drouz during personal discussions. (2)

Early investigations in Syria revealed the presence of a large number of hema-like reservations, maintained at present in groups. The local name for these is mahmia (plural mahmiat), derived, like ahmia, from the Arabic word for protection. The term marah or mahmia is used along the Syrian-Lebanese border, while koze is Kurdi for hema. The reserves along the Syrian-Lebanese border (rainfall about 300 mm) are maintained chiefly for winter foraging by goats. The 1958 Forest Protection Act designed to control the foraging of goats in forest areas (including most of the mountainous areas of Syria) is enforced by confiscation of the mahmiat or by slaughter of the goats. However, in border areas, the government has not enforced the act.

In non-border areas, where the act is enforced, it has resulted in the confiscation of some 30 mahmiat. However, after control of the mahmiat was taken over by the government, poor management has resulted in excessive cutting of the edible sindyan trees (Quercus sp.) for firewood and charcoal, which in turn has denuded hills and mountains, leaving the land vulnerable to erosion. Where the mahmiat remained under the control of the Syrians, this has not occurred. These remain carefully managed and grazed to maintain good tree, shrub, and grass cover.

A mahmia studied in more detail was found to have a vegetative cover mainly composed of sindyan trees, za'rur (Crataegus sp.), Phyllyrea media, and a comparatively small number of the prickly, shrubby billan (Poterium spinosum). A rich understory of clovers, vetches, and a large number of annual and perennial grasses at an early stage of development were present. About 50 goats were grazing this 50-hectare reserve.

The vegetative cover in the surrounding areas was greatly deteriorated. The shrubby billan was the dominant plant species, indicating previous forest cover. Remnants of the heavily grazed and cut sindvan trees are scattered over the area. The mukhtar of the nearby Elhawi village stated that these trees were cut down within a few years after the 1958 Forest Protection Act. The only remaining mahmiat are the trees within the village cemetery.

These findings indicate that humans rather than goats are probably responsible for the destruction of the forests. Elimination of goats has not proven to be the answer; in fact it has aggravated the situation. As demonstrated in the protected mahmiat. a system of grazing management with the correct numbers of goats and sheep has proven its efficiency. These systems, whether named hema, mahmia, or marah, have been developed by the local people over countless decades and could not successfully be replaced by systems planned for different environmental and sociological conditions. In Syria, the result has been nearly complete denudation of its highly productive range and forest lands and a loss of about one million goats.

A mahmia system of grazing, called koze, has been traced along the

Syrian-Turkish-Iraqi borders. Various kozat in the areas of Al Qamishli, Makekizeh, 'Ayn Diwar, and Tall Kushik (rainfall 400-500 mm) were visited. In principle, there appears to be no difference in the methods of maintenance and utilization for such reserves. Tribal tradition is adequate for controlling rights and responsibilities.

The local people usually are reluctant to give information about the kozat, fearing that they may lose their right of use because of government intervention. Inspection of a reserve southeast of 'Ayn Diwar, close to the Iraqi frontier, showed the plant cover to consist mainly of Chrysopogon gryllus (shafer), Palaris tuberosa (giachon), and Hordeum bulbosum (korram). Shafer is highly rated by the local shepherds, owing to its high palatability and long season of growth, especially during the drier season of the year. Its voluminous, deep root system also has great value as a soil binder.

Tribal tradition allows most of these reserves to be grazed only during the winter season, between midDecember and the end of

March. Areas where strafer and/or giachon constitute most of the plant cover may be grazed in the summer season, however.

There is evidence that a number of native and/or exotic perennial plants that have proven successful at the Himo Experiment Station (Al Qamishli) could be tried for reseeding and expanding programs of the kozat system of grazing in this and adjacent regions in Turkey, Iraq, and Iran.

Another type of hema has also been observed in the Hassia-Breig region, located south of Homs between the main roads to Damascus and the Lebanese borders. This unique range reserve, which covers a surface area of about 40,000 hectares of rough, poor soils, was, until 1958, part of a feudal system of land tenure that came to an end through the enforcement of a land reform act. The system of grazing in this vast hema had been organized through permits for grazing rights to be given to the shepherds belonging to the adjacent villages, against a fixed rental value of about SP1 per goat or sheep per season (that is, about US$1 per four animals). Since this hema is considered to be potential forest or subforest land, it was confiscated by the government and has been transferred to the Forest Department.

Practically the same system of grazing management has been maintained, except that about 600 ha are now completely protected from grazing to allow for natural forest regeneration (Zweitina area). The rest of the area is now grazed only by flocks of sheep; previously, it was grazed mainly by goats. It seems that a smaller number of animals are now being grazed throughout the year, compared with a much larger number during the winter season only.(3)

In the higher altitude of the hema (Zweitina area) at 80~900 m, where grazing has completely stopped (since August 1972), regeneration of Pistacia palaestina, Pyrus syriaca, and Amyzgdalus orientalis has been satisfactory. Otherwise, all over the hema, Artemisia herba-alba and Salsola vermiculata form the main vegetative cover, indicating that annual precipitation might be between 200 and 250 mm.

In a few villages south of the Hassia-Breig region, smaller mahmiat are managed as range reserves for the benefit of village flocks. Both ourf and government orders support efficient control of these reserves.

The possibility of application and use of the same system of grazing in adjacent areas and under similar conditions appears encouraging.

Neglect of the hema and its consequences

In Saudi Arabia, marked denudation of plant cover occurred in most of the previously protected ahmia as a result of free grazing of these reserves that took place through misunderstanding of the 1953 decree. While this decree was meant to replace the grazing rights of ahmia only so long as they were protected by the local ahmirs in different regions with grazing animals owned by the government, the decree was interpreted by the various authorities as withdrawal of all controlled grazing measures, thus allowing free grazing. Resultant denudation of the plant cover in these range reserves led to serious soil erosion associated with frequent, destructive floods. Consequently, most of the ancient dams and water conservation systems that previously worked efficiently under the prevailing climate conditions and protective measures of the hema system failed to withstand the flooding and siltation that occurred when protective vegetative cover was destroyed.

Meanwhile, large amounts of runoff water have created another serious problem. After any appreciable rainstorm, the floodwater soon collects in the wadi beds, then disappears into the sea, into salty depressions, or nearby sand dunes. The scarcity of plant cover and destruction of water conservation works have thus become major factors inhibiting percolation of rainwater. The decreased percolation in most areas has in turn reduced the flow of spring water. A survey showed that the old dams constructed in pre-Islamic times are now useless. Samalagee Dam, 400 m wide, and situated below Hema Thumula, can store no water because the spillway was destroyed by floods. The construction of this gigantic dam proves that ancient peoples had a keen interest in water conservation works. Five more dams, or sad, close to Hema Nageeb, have met a similar fate, and about 10 surrounding villages have been adversely affected. Wells have almost dried up, and villages are constantly asking for help. Altogether, there are 20 ruined dams (sad) in the area and about 40 smaller sad known as stony okad.

Sad Saisad is an example of another neglected dam. It was probably constructed by Moawia, the fifth Islamic caliph, who succeeded Muhammad the Prophet 13 centuries ago. The Ministry of Agriculture of Saudi Arabia has lately authorized the development of a soil, water, and vegetation plan in the Sad Saisad area to include a part of the adjacent abandoned Hema Saisad, thus reviving its protection.

The only two springs (gheil) that kept flowing after a long period of drought have their main rainfall catchment areas along two wellprotected ahmia: Hema al Nomoor (the largest hema in the At Ta'if area) and Hema al-Machada.

Recharging of the groundwater table by reconstruction of the ancient dams and waterworks and revegetation of the ahmia would greatly increase water supplies for the deficient area at At Ta'if.

Hema in the range improvement and conservation programs in the near east

The hems system was once common in parts of the Arabian Peninsula and is still used in parts of Saudi Arabia, Yemen, Oman, and Syria. It originated in the Near East and is suitable as a means for controlled grazing in selected areas in arid, semiarid, and mountain ranges where nomadic grazing is the only system practiced. Carefully protected ahmia would furnish fodder reserves essential for stability of nomadic growing. They would also change the attitude of the people towards the range, introducing the philosophy of protection and improvement instead of exploitation.

Ahmia, moreover, give the range manager an insight into the potential forage productivity of range sites and indicate how much improvement can be expected when large areas of run-down ranges are upgraded and given prudent care. Although soil and water conservation programs might include several physical or mechanical methods, in most cases there is no substitute for revegetation for which the hema system has proved its efficiency.

Introduction of the system to new areas in this region, or to localities where it has previously been practiced, might require different techniques from one country to another. In most cases, however, this has to be a gradual rather than an abrupt change.

In Saudi Arabia, concepts have lately been changed to support ahmia. The Royal Decree of 1953, which allowed for free grazing of the historical ahmia, has been clarified so as to exclude tribal or personal ahmia. To demonstrate the role and importance of the system, part of Hema Saisad (one of the abandoned historic ahmia) east of Taif, was put under protection in 1965. Plans have been made by the government to establish a range experiment station within this hema

During 1968, the Syrian Arab Republic approved the execution of a World Food Programme/Food and Agriculture Organization (WFP/FAD) assisted project in which the range and forest potential of the Gebel Abou Rejmaine, north of Palmyra, would be managed as a hema within a project for stabilization and development of nomadic sheep husbandry. The Al Ommor tribe, supported by governmental and WFP assistance, has become responsible for protection, development, and use of this mountainous area. The successful introduction of hema in the form of range cooperatives has encouraged expansion of the pioneer work. The number of hema cooperatives had increased to 46 in 1979, covering around 4 million hectares. The recent discovery that ahmia do exist in a number of localities in Syria, indicating previous existence in similar areas, might allow for expanded application of this system. It could also be integrated within pilot agricultural development programs.

In certain cases, minor changes in forestry, land tenure, and/or range protection acts legalize these reserves. The system could also be integrated within a grazing act suitable for many parts of the countries in the Near East.

Groups of people meeting in the various countries where hema has been maintained are of the opinion that if previously practiced rights of usufruct were restored or allowed to be given, subject to fulfillment of certain requirements, regeneration of vast areas of range or forest land could be achieved.

NOTES

1. Based on Omar Draz, 1985

2. A unique type of hema existed close to Damascus for about five centuries, up to 1930, where (according to government documents), a 100 hectare area had been maintained as pastureland for aged or unfit horses until the end of their lives (Draz, 1985).

3. This hema has been developed to become the Hassia government range and sheep center.

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Wildlife land use at the Athi River, Kenya

BY DAVID HOPCRAFT

Background

The research described in this case study, which began in 1965, was initiated in order to understand and prevent the spread of desertification in Kenya. In earlier research, the author had compared the remaining productive lands with the deteriorated lands within similar regions, concluding that deterioration and destruction followed substitution of domestic stock for indigenous animals, which were often killed to reduce competition for forage with cattle.

If this theory were correct, would it then be possible to reverse the destructive process by returning to the use of native animals? Would such a land-use system protect and restore the rangeland resource? Could native species be harvested for meat and hides, like cattle? Could ranching of native species be as economically productive as cattle ranching, but without the negative environmental effects? Could conservation of native species be enhanced through production?

At this point, the National Science Foundation (NSF) was approached for research funds to test the hypothesis that utilization of a natural system with native animals would be nondestructive, yet productive in comparison with usage of imported stock. An experiment was designed to compare cattle with a native species, to monitor the comparative effects on grasslands, and to measure the offtake of meat and hides. NSF agreed to fund the project. A uniform 300-acre plot of land at the Athi River ranch was fenced off and divided down the middle. One side was stocked with gazelle, the other with cattle, and the research began. Over a three-year period, the results of the research answered a number of significant questions.

From an ecological perspective, the effects on the range of the two species were quite dissimilar. During the study period, grass cover in the cattle enclosure was significantly reduced, climax vegetation among grass species was reduced, and the soil toward and around the watering site was highly degraded. In contrast, there was 32 percent more cover in the gazelle enclosure, 100 percent more climax species, and no deterioration of the land.

Cattle clearly were affecting this semiarid rangeland. They are water-dependent animals and must walk daily to water, trampling vegetation underfoot and compacting the soils. Cattle also have a specific food preference and cannot use vegetation evenly as do game animals. Certain grass species are therefore eaten while other nonpreferred species become entrenched, subsequently diminishing the production quality of the whole.

Data indicated an advantage to gazelle production in terms of leanmeat production per acre. Game animals have a higher ratio of usable carcass to live weight than do cattle, thus providing 10 percent higher usable carcass. Game animals usually have only 1 percent fat, as opposed to more than 20 percent fat in cattle. Lean meat was thus 47 percent of the gazelle and only 32 percent of the cattle carcass; it had no saturated fats and had not been injected with hormones. It also was noted that indigenous animals spend far less energy than do cattle in overcoming harsh environmental conditions such as disease, drought, and sparse vegetation, and thus more energy is available for growth.

Some early findings

In 1976, the author received a grant from the Lilly Endowment for the large-scale application of his findings. The funding allowed construction of an 8.5-foot fence around the 31-mile perimeter of the ranch, a major undertaking that required 15 months to complete. The fence enclosed more than 2,000 native animals representing 15 species.

Once the fence was completed, the project faced extraordinary delays while securing the Kenyan government's permission to market the game meat. In 1981, the necessary permits were granted for the project to enter its operational phase. At present, the ranch, referred to hereafter as WRR (Wildlife Ranching and Research), is the only commercial venture authorized to harvest wildlife and market the meat in Kenya.

From January 1981 until January 1984, cattle numbers were reduced from a biomass of 86.3 to 44.4 kg per hectare (table 10-1). During this period, the economically important species of wildlife, comprising the vast majority of native animals on the ranch, increased from 12 to 16.3 kg per hectare. The policy of destocking cattle to make room for the wildlife populations to grow has led to a 50 percent reduction in herbivore biomass over the last four years, dramatically relieving forage pressure on the land.

Over the study period, cattle and wildlife have coexisted on the ranch. Animal census counts are regularly carried out on the ground, with aerial counts used to check accuracy. The counts show a 12percent yearly increase in wild animal populations after harvest is subtracted.

Species	Jan. 1981 No.	Biomass (kg)	Jan. 1982 No.	Biomass (kg)	Jan. 1983 No.	Biomass (kg)	Jan. 1984 No.	Biomass (kg)
Thompson Gazelle	622	9,952	555	8,880	727	11,632	970	15,520
Grant's Gazelle	460	16,100	360	12,600	335	11,725	307	10,745
Hartebeest	446	37,910	617	52,445	665	56,525	594	50,490
Wildebeest	264	33,000	253	31,625	335	41,875	445	55,625
Subtotal	1,792	96,962	1,785	106,550	2,062	121,757	2,316	132,380
Biomass (kg/ha)		12		13		15		16.3
Cattle	2,360	680,000	1,876	540,288	1,500	432,000	1,235	355,680
Sheep	475	19,000	503	20,120	150	6,000	91	3,640
Subtotal	2,835	699,000	2,379	560,408	1,650	438,000	1,326	359,320
Biomass(kg/ha)		86.3		69.2		54.1		44.4
Total Biomass		795,960		665,958		559,757		491,700
Biomass Density kg/ha		98.3		82.2		69.1		60.7

Note: Overall biomass density by the end of 1984 is reduced to approximately 50 kg/ha.

Table 10-1 Animal Populations and Wildlife Ranching and Research, 1981-1984

Year	Number Harvested				
	Thompson Gazelle	Grant's Gazelle	Hartebeest	Wildebeest	Total
1981	243	154	97	36	530
1982	145	88	186	108	527
1983	187	76	179	120	562
1984	151	55	287	234	727

TABLE 10-2 Wildlife Offtake at Wildlife Ranching and Research, 1981-1984

TABLE 10-2 Wildlife Offtake at Wildlife Ranching and Research, 1981-1984

Year	Number Harvested				
	Gazelle	Thompson Grant's Gazelle	Hartebeest	Total Wildebeest	
1981	243	154	97	36	530
1982	145	88	186	108	527
1983	187	76	179	120	562

1983	187	76	179	120	562
1984	151	55	287	234	727

For the first 21 months, harvest was confined almost entirely to surplus males. This altered the sex ratio of the herds to favor females 10:1. This policy allowed growth in breeding stocks while providing saleable offtake. Females were subsequently added to the harvesting program to maintain this ratio.

During the first year, the natural increase of wildlife, adding those harvested to the increase in numbers, totaled 40 percent. With the increased female to male ratio, this total climbed to 50 percent for the following years. This offtake rate was very high, considering that the average offtake rate for cattle in the area averages only 17 percent.

Table 10-2 shows actual numbers and weights of animals harvested over the four-year period. Gazelle were harvested rigorously and the other species lightly at the start, but as the figures show, this was corrected over the four years. The average weight of animals harvested declined significantly over the period, reflecting the decline in the average age structure of the herd. Of importance is the associated quality and tenderness of the meat, which is very apparent to the consumer.

The fourth year, 1984, does not fit with the preceding years because of a policy change in ranch operations and because of the worst drought on record. The policy change was to increase the offtake of animals, mainly because of the drought, but also because of the established policy of maintaining and developing markets for wildlife products. The long-term goal is to expand the base of operations, and continue to build a wildlife industry. Indications were that the ranch was on the verge of receiving license to expand its production base. It is interesting to note that demand for the product continues to exceed supply.

Year	Carcass Price/kg	Average Sale Price/kg	Kg Sold	Number of Horns*	Total Income (K/sh)**
1981	25	7.5	19,330	530	636,000
1982	26	8.5	24,945	527	819,000
1983	31	34.1	26,661	562	1,032,000
1984	35	38.5	35,910	727	1,527,935

*An assumed price of 200 K/sh per animal is used for hides and horns.
**An approximate conversion through the period would be $1 = 10 K/sh

Note: The income recorded above was that actually obtained from the wildlife ranching operations, using assumed figures only for hides and horns. (Due to government restrictions, these items are yet to be sold.)

TABLE 10-3 Gross Returns from Wildlife, 1981-1984

TABLE 10-3 Gross Returns from Wildlife, 1981-1984

Year	Price/kg Carcass	Average Sale Price/kg	Kg Sold	Number of Horns*	Total Income (K/ah)**
1981	25	7.5	19,330	530	636,000

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1982	26	8.6	24,945	527	819,000
1983	31	34.1	26,661	562	1,022,000
1984	35	38.5	35,910	727	1,527,935

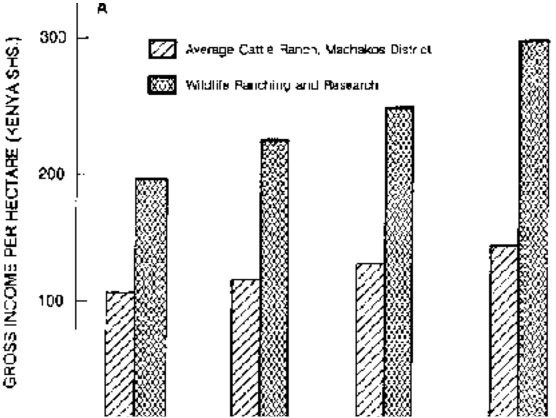
*An assumed price of 200 K/ah per animal is used for hides and horns.
**An approximate conversion through the period would be $1 = 10 K/ah

Note: The income recorded above was that actually obtained from the wildlife ranching operations, using assumed figures only for hides and horns. (Due to government restrictions, these items are yet to be sold.)

In 1984, sales of 35,000 kg of dressed venison were recorded; the meat sold as fresh carcasses, cuts and roasts, cooked and smoked sausages, and biltong or jerky. An average price of over 39 K/sh (Kenya shillings) per kg gave a gross return of 1.37 million K/sh for meat products. Table 10-3 shows gross returns from wildlife over the four-year period.

How does the data relate and compare to traditional cattle ranching? To answer this we will look at an economic survey commissioned by Cornell University specifically to establish the viability of cattle ranching in the area of WRR. The average ranch size of the 10 ranches sampled was 9,193 hectares. Averages of all the physical and economic measures and the technical coefficients of these ranches were used to construct a budget representing the average commercial cattle ranch in the district.

We will use this average scenario because it reflects actual production and income figures for the area in the same way as our wildlife data represents actual findings on WRR. Costs and prices used are for the year 1980, yielding gross returns for the ranch of 919,200 K/sh. Cash expenditure was 830,054 K/sh, leaving a net profit of 89,146 K/sh. Assuming sales averaging 6 K/sh per kg live weight (the prevailing prices), and dressing out percentages of 50 percent, these figures translate into a production level of 8.33 kg per hectare of carcass weight, yielding gross and net returns of 100.00 and 9.70 K/sh per hectare, respectively, for 1980. Assuming a 10 percent increase per year in both income and cost, gross and net returns are shown for the succeeding four years in figure 10-1.



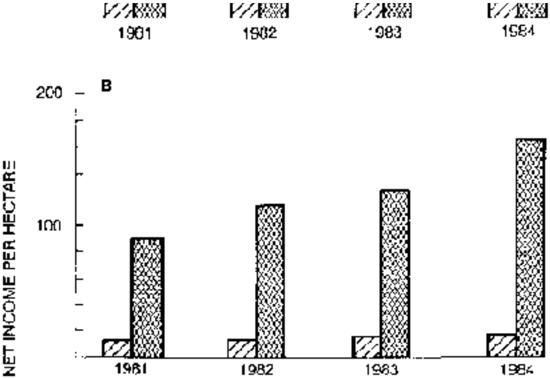


FIGURE 10-1 Comparison of gross and net returns.

Figure 10-1 compares this gross and net income with WRR income, a mixed wildlife and cattle operation. The wildlife data is from production and income levels for wildlife on WRR. The stocking rate of the average cattle ranch in the sample was 1 livestock unit per 6.5 hectare. Assuming 400 kg per livestock unit, this translates to

61.54 kg per hectare. Only in 1983 and 1984 do cattle on WRR fall below this stocking rate (see table 101).

It is assumed therefore that the mixed ranch carried the average stocking rate for cattle in the survey of 61.54 kg per hectare for 1981 and 1982 along with the WRR wildlife stock, and that in 1983 and in 1984 the numbers of cattle and wildlife are as actually existed on WRR, shown in table 10-1. This shows gross returns for WRR nearly double that of the average cattle ranch, and net returns almost 10 times greater.

A further economic advantage of the switch to wildlife was the freeing of capital achieved from the sale of domestic animals. Over the four-year period in question, WRR sold more than half its cattle stocks, or nearly 50 kg per hectare, some 400,000 kg live weight. This has a cash value of some 2.8 million K/sh, which, at 1983 exchange rates, exceeded a quarter of a million dollars. Clearly, this money could go toward the conversions needed for wildlife utilization, or be invested elsewhere to significant advantage. The same advantage would be realized on many ranches in Kenya that already have significant stocks of wildlife. In areas lacking wildlife populations, purchase of stocks would necessarily negate this one-time windfall.

Meat production from the average cattle ranch in the same survey is 8.33 kg per hectare of carcass weight. The mixed system on WRR (using the same assumptions), averages 30 percent greater production over the four-year period. Production from 1981 to 1984 would be 10.75, 11.45, 10.66, and 10.49 kg of carcass per hectare, respectively.

Through the 1984 drought, WRR continued to supply game carcasses in good condition to the market. Every week without fail, harvesting and sales of the wildlife continued. Cattle ranches in the area suffered seriously, with emaciated animals supplying little to the market.

There is no doubt that the experimental and demonstration ranch, WRR, has benefited enormously from the inclusion of wildlife as the focus of expanded operations. Gross income is double that of the average cattle ranch and net income 10 times greater.

Income for the game, compared with cattle operations on WRR is substantially higher, reflecting higher offtake rates, higher product prices, higher dressing percentages, and the different sales method required for the system. The very high offtake rates for wildlife reported here are among the most important findings of the WRR operations, pointing to high fecundity and reproductive growth of wild communities.

These findings dramatically contrast assertions in a 1983 Cornell University study. Surprisingly, this study drew definitive conclusions on the complex question: game or cattle for meat production in Kenyan rangelands? based on only eight months of involvement with the initial stages of the WRR wildlife operations in 1981. This was before management or marketing was stabilized, and before reproductive growth or offtake rates reported here were established.

Prices for venison on the international market average nearly twice those of beef, greatly enhancing the value of wildlife use. Considering the low fat and the absence of chemicals, hormones, and antibiotics (the presence of which tend to reduce the price of domestic meats in the Western world), this price differential is anticipated to be long lasting.

Conclusion

The system of land use for semiarid rangelands developed at WRR, although in full operation for less than five years, demonstrates a method for protection and regeneration of the land resource. The reestablishment of natural species diversity enables the land to return to a positive condition, favoring the entire range of native animals, plants, birds, insects, and soil organisms.

From a commercial perspective, the selective harvesting of game animals has been a notable success. Net returns per acre are 10 times those of the average cattle ranch in the area, yet the stocking of wildlife is still one-sixth that of normal cattle numbers. A new industry has been developed in Kenya as a result of this effort, and demand for wild game products from local and foreign markets has developed rapidly.

In a variety of forms, the practice of game ranching has steadily gained momentum worldwide over the past 20 years. Successful harvesting operations are ongoing in New Zealand, South Africa, the Soviet Union, and elsewhere. The focus of those activities, however, is generally on meat production or sport hunting exclusively. The author's method, in contrast, is multidimensional and more relevant to the specific needs of areas where both economic development and resource protection are essential. His wildlife land-use system rests midpoint on the line between conservation and production, serving both while shortchanging neither.

We must now ask what should be done with the encouraging results of this project. Can the model be applied in similar circumstances elsewhere? Does it offer a solution to the desperate problems of deteriorating rangelands in Africa and elsewhere, with the associated problems of food production and income generation? Is the system flexible enough to be applied by or for people with less specialized skills? How does it serve the interests of the indigenous population - the pastoralists and others?

Camel husbandry in Kenya: Increasing the productivity of ranchland

BY J.O. EVANS AND J.G. POWYS

Introduction

As ranchers in Kenya, the authors of this paper have always sought to obtain maximum production from their land. Several years ago, it became apparent that camels might contribute to this aim. Initial results and impressions are reported herewith.

Location

Camels were introduced to four ranches between 1974 and 1978 (figure 11-1). They are:

· Galana Ranch (more than 400,000 hectares), which is south of the equator in the hinterland of the Kenya coast. It lies on the fringe of the coastal rainbelt in semiarid savanna at an altitude of 270 m above sea level and receives an average rainfall of 550 mm. Tsetse fly (Glossina spp.) and trypanosomiasis occur on parts of the ranch.

· 01 Maisor, Kisima, and Ngare Ndare, which lie just north of the equator in Kenya's Laikipia district at altitudes of between 1,730 and 1,890 m above sea level. All three ranches comprise approximately 12,140 hectares and receive an annual average rainfall of 580 mm.

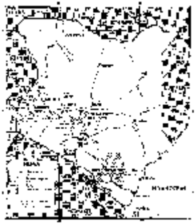


FIGURE 11-1 Map of Kenya showing location of ranch" and sources from which camels were obtained.

Vegetation

The vegetation on the Galana Ranch is influenced by declining rainfall from east to west. In the extreme east, there is thick coastal bush and forest containing Afzelia quanzensis, Brachystegia spiciformis, and Bombax rhodognaphalon. This merges into light Diospyros mespiliformis parkland, which in turn gives way to Acacia and Commiphora woodland. In the westernmost and lowest rainfall zone, Commiphora spp. dominate. In all zones, there is extensive open grassland composed of Chloris spp., Schoenefeldia transiens, and Aristida spp., among a wide range of other species.

The other three ranches - 01 Maisor, Kisima, and Ngare Ndare - have predominantly Themeda, Setaria, Hyparrhenia, Loudetia, and Cynodon grasslands, scattered widely with Acacia seyal, A.gerrardii, and A. drepanolobium. Bush and thicket containing Euclea, Rhus, Grewia, and Acacia brevispica are also widespread.

Livestock

All four ranches carry Boran cattle stocked at 4-6 hectares per beast, Merino or crosses of Merino and Dorper sheep stocked at 1-3 per head of cattle (with which they compete for grazing), and indigenous goats crossed with exotic male introductions. The goats browse on low and medium-sized bushes, controlling them and opening them up to permit the growth of grass that would otherwise be shaded out. Their small size limits their effect on the larger trees.

Introduction of camels

In 1974, 30 camels were purchased in the Wajir and Garba Tula districts of northern Kenya and walked to the Galana Ranch. In 1975, an additional 100 females were acquired in Moyale; 70 were moved to Galana and 30 to Ngare Ndare. Between 1975 and 1977, a number of camels were bought from the Turkana and Pokot people of the Rift Valley and moved to 01 Maisor, where they now number 102. In 1978, 20 females and a few males were bought in the northern Wajir district and trekked to Kisima. Four commercial camel herds have thus been established.

The purposes of acquiring camels were essentially experimental, but several premises underlay the decision to experiment:

· By taking a spectrum of vegetation not used by the other domesticants, camels would increase the productivity of all four ranches.
· By eating many plants that grow among grass but are ignored by

cattle, sheep, and goats, the camels would improve the pasture for the other animals.

· If camels provided milk for herdsmen normally dependent on a supply from ranch beef cows, beef calves would not be deprived and would show better growth.

· By providing transport, camels would be an economic substitute for other forms in moving herdsman's chattels, rations, and equipment, thus enabling the cattle herds to make best use of available grazing (particularly on Galana).

· A base would be established for exploring and, later, exploiting an increasing demand for camel meat in certain Kenya towns, and the market for live camels in Arab states.

· A base would be established for developing a wider trade in camels from Kenya's stock of more than 600,000.

· The possibilities of making camel milk cheese and using camel wool could be investigated.

Management and adaptability

The camels are herded during the day and penned in thorn enclosures (bomas or zaribas) at night. These enclosures are in close proximity to others holding cattle, sheep, and goats. Their use is primarily as protection against predators and thieves. They are moved to new locations every few weeks.

The camels withstood the transfer from low altitudes and very arid climates to the high altitudes and slightly wetter conditions of 01 Maisor, Kisima, and Ngare Ndare. Some were in poor condition on arrival, but thrived and improved rapidly.

They are provided with a mixed mineral lick containing phosphate, calcium, salt, and trace elements for which they show greater appetite than cattle. These minerals are thought to be responsible for a better bone structure apparent in the young animals grown on the ranches.

The Somali camels from Wajir, Moyale, and Garba Tula were tame and tractable. Those from Turkana and Pokot in the Rift Valley were nervous, head shy, and inclined to kick. Gentle handling and kindness changed this and they are now docile and easily managed.

Number of Camels	Calf Sex	Birth Date D M Y	Interval	Remarks
4	M	15 12 76		
	F	15 8 78		20 months
5	M	16 4 77		Died?
	M	6 10 78		18 months
6	F	9 5 77		Killed by lion
	M	10 4 79	23 months	Suckled other calf
9	F	24 5 77		Died 5 6 77
	F	10 7 78	14 months	
10	M	9 5 77		
	F	14 7 79	26 months	
12	M	13 12 77		Died?
	M	18 7 79	26 months	
13	M	10 4 78		Died
	F	10 6 79	14 months	

14	M	20	11	77	
	M	5	10	79	23 months
15	F	26	11	77	
	M	21	9	79	22 months
20	M	20	11	77	
	F	22	7	79	20 months
23	M	30	1	78	
	M	25	10	79	20 months

TABLE 11-1. Calving Records at Ngare Ndare Ranch

TABLE 11-1. Calving Records at Ngare Ndare Ranch

Number of Camels		Birth Date			Interval	Remarks
	Calf Sex	D	M	Y		
4	M	15	12	76		
	F	15	8	78		20 months
5	M	16	4	77		Died?

5	M	10	4	77		Died?
	M	6	10	78		18 months
6	F	9	5	77		Killed by lion
	M	10	4	79	23 months	Suckled other calf
9	F	24	5	77		Died 5 6 77
	F	10	7	78	14 months	
10	M	9	5	77		
	F	14	7	79	26 months	
12	M	19	12	77		Died?
	M	18	7	79	26 months	
13	M	10	4	78		Died
	F	10	6	79	14	

					months	
14	M	20	11	77		
	M	5	10	79	23 months	
15	F	26	11	77		
	M	21	9	79	22 months	
20	M	20	11	77		
	F	23	7	79	20 months	
23	M	30	1	78		
	M	25	10	79	20 months	

Several males and some females were trained for riding and baggage transport. This was easy and was accomplished more quickly than would have been the case with horses. They show strong individual character and are very pleasant animals to work with.

Reproduction and lactation

Maturity has been reached at between 6 and 8 years. Data from 11 females on the Ngare Ndare ranch are presented in table 11-1 and show an average calving interval of 22 months (range 14-26 months).

Camels	Date calved D M Y	August 10	September 29	October 28
5	6 10 78	1.13	1.70	Dry
6	3 4 79	3.40	3.40	3.97
13	10 6 79	3.12	3.69	3.40
26	27 6 79	1.98	2.27	2.55
10	14 7 79	7.00	4.26	4.54
12	15 7 79	2.27	2.84	4.54
20	23 7 79	2.27	2.84	3.40
27	18 9 79	---	3.40	3.40
15	21 9 79	---	3.40	4.54

TABLE 11-2 Milk Yields (in liters), Ngare Ndare Herd. Morning Milking

TABLE 11-2 Milk Yields (in liters), Ngare Ndare Herd. Morning Milking Records Only; Very Dry Conditions.

	Date calved			**August 10**	**September 29**	**October 28**
Camels	**D**	**M**	**Y**			
5	6	10	78	1.13	1.70	Dry
6	3	4	79	3.40	3.40	3.97
13	10	6	79	3.12	3.69	3.40
26	27	6	79	1.98	2.27	2.55
10	14	7	79	7.00	4.26	4.54
12	15	7	79	2.27	2.84	4.54
20	23	7	79	2.27	2.84	3.40
27	18	9	79	---	3.40	3.40
15	21	9	79	---	3.40	4.54

15	21	9	79	---	5.40	4.54

Estrus has occurred at 4.5-10 months postpartum and, in one instance in which there was a defective udder, 28 days.

Three gestations were recorded accurately; 2 male calves at 373 days, and 1 female calf at 393 days.

The young commence browsing at 1 month if the females have little milk, but at 2 months if milk is abundant.

In tables 11-2 and 11-3 some data on milk yields are presented from Ngare Ndare and Galana ranches. Although scanty, they illustrate a potential that is within the range of that recorded by Knoess (1976) from the Awash Valley, Ethiopia.

Veterinary notes

Deaths have occurred from trypanosomiasis, pneumonia, and hydatidosis in Turkana and Pokot camels; all of these diseases were contracted before the camels were purchased. Since purchase, they have suffered from foot abscesses, Corynebacterium abscesses, joint-ill (one calf on 01 Maisor), eye infections, mange, and (on Galana) trypanosomiasis.

Off-color animals treated with tetracycline and compound antibiotics have responded well.

Although worm egg counts are not necessarily indicative of a serious problem with internal parasites, animals have been dosed with nilverm, nilverm injectable, panacur, nemafax, thibenzole, and neguvon injectable, with positive results.

The Galana animals are kept under prophylactic cover for trypanosomiasis with apparent success by using antrycide sulphate and antrycide prosalt (both drugs now no longer available).

Camels	6 am	11 am	3 pm	6 pm	Total
5	2	1.5	2	2	7.5
17	2	1.5	1.5	2	7.0
20	2	1.0	1.0	2	6.0
66	2	1.5	1.5	2	7.0

Average daily milk record, morning and evening milking only (liters)

Camels	am	pm	Total
7	3.0	3.0	6.0
17	3.5	3.0	6.5
20	3.0	2.5	5.5
66	3.5	2.0	5.5

TABLE 11-3. Milk Yields (in liters) Galana Herd. Comparison of Milk Records from 4 Females Milked 4 Times a Day and Twice a Day.

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Average daily milk record, morning and evening milking only (liters).

Camels	am	pm	Total
7	3.0	3.0	6.0
17	3.5	3.0	6.5
20	3.0	2.5	5.5
66	3.5	2.0	5.5

All animals have been vaccinated against blackquarter and anthrax. The umbilical cords of newborn calves are tied with iodine-dipped ligatures against joint-ill infection.

Mange has been serious in wet weather. Treatment with BHC and alugan has been moderately successful, but delnav (organophosphorous) appears to be most effective. A rubbing-post draped with sackcloth soaked in old engine oil with delnav added provides a useful method of administration.

Brucellosis appears to be prevalent in the Galana herd. Extensive tests were carried out recently by the Kenya Veterinary Department. The tests were not conclusive, and it would appear to be very difficult to isolate Brucella organisms in camels in the absence of freshly aborted fetuses. Thirteen blood samples taken in April 1978 from 01 Maisor females were negative.

An attempt was made to infect two camels at Ngare Ndare with corridor disease caused by Theileria lawrencei. The serum was negative for antibodies and it was presumed camels are not susceptible to this disease. Johne's disease was isolated in serological tests on Galana but did not appear to cause a problem.

Foot abscesses and abscesses at the base of the neck and on the rump cause considerable distress. Abscesses in the gland can become large and require surgical removal. Pus from an abscess in one animal revealed Corynebactcrium pseudotuberculosis and from another animal B-hemolytic streptococci.

There was a virulent outbreak of foot-and-mouth disease, type S.A.T. 2, in cattle, sheep, and goats on 01 Maisor, with which the camels were in close contact; the camels were unaffected.

The breeding herd on Galana took two years to acclimatize and commence breeding regularly. When first introduced to the area, they were not given any prophylaxis treatment for trypanosomiasis for more than a year. Abortions and premature births are common; a great many females were unable to feed their calves.

Since they were injected regularly with antrycide sulphate, the health and production of the herd improved dramatically.

Economics

While the price of camera is comparable to that of good quality cattle, the distance from the ranches at which they have had to be purchased has made their acquisition very costly.

Direct expenses incurred in their upkeep have proved less than those for our cattle (KSh 70/- to 80/per year without overhead). This is mainly because they have not needed the regular and obligatory dipping or spraying required by cattle to protect them from the ticks and tick-borne diseases to which cattle are prone.

The slow reproductive rate of 22 months compared to less than 14 months for ranch cattle, and slow maturing rate of 6-8 years against 3-4 years for finished steers, indicates a poor economic potential.

The return from camels might be improved with experience and improved husbandry. It should be possible to reduce the calving interval to 18 months (Knoess, 1976). Milk production might also be taken into account.

Even with such improvements, cattle will remain the more profitable animals. However, we must emphasize that our camel productivity is additional to and in no way competitive with our beef production or any other livestock on the property.

We have every hope that the quality of our camel stock will improve; our foundation animals tended to be culls that the sellers thought to be defective. It might speed up growth and individual quality if young animals could be weaned and hand fed (the Turkana say that they rear camel calves successfully on cow's milk).

When purchasing stock, it is advisable to try and buy unbred females and to avoid buying heavily branded animals, as this is generally an indication of some defect or illness. The pastoral people of Kenya use the practice of firing (the application of hot metal) for almost any ailment.

NOTE

Thanks are due to the Kenya Department of Veterinary Services and those members of the veterinary profession who have helped and advised us. The camel lore and good advice received from members of the Somali and Turkana tribes are greatly appreciated by the authors.

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The potential of faidherbia albida for desertification control and increased productivity in Chad

BY ROBERT D. KIRMSE AND BRIEN E. NORTON

Reforestation using Faidherbia albida (also known as Acacia albida) has been proposed as a mechanism for combating desertification trends in the Sahel. This tree is characterized by a deciduous habit in the wet season; it is valuable for fodder, as a hardwood in woodwork industries, and for enhancing soil fertility of cropland. In a three-year project described in this case study, the establishment of Faidherbia albida plantations in cultivated fields in central Chad is conceived as a focal point to coordinate resource conservation and land development programs. Several hundred thousand young trees were established and about 2,500 farmers and their families participated in the revegetation program. The success of the project must be evaluated, however, in terms of the prospects for longterm benefit and recognizing the sociological problems of assistance programs.

Background

Chad is one of the poorest countries in the world, with a per capita income of less than US$100. It is a landlocked Sahelian country with all of the complex problems associated with a fragile arid ecosystem and an economy based on small-scale subsistence farming and livestock grazing. It has a short growing season, poor soils, uneven rainfall patterns, and is subject to cyclical droughts.

During the drought period between 1970 and 1973, agricultural production was reduced by approximately 62 percent (Government of the Republic of Chad, 1977). Per capita food production, even before the drought, declined 32 percent from 1961 to 1970.

These trends may be indicative of two developments: an expanding population on a limited land resource, and a degradation of the land's productivity. It is probably a combination of these two factors that results in a poor country's getting poorer and less able to feed itself, much less protect its ecosystems from instability and degeneration.

In the Sahel, modernization is encouraging migration to the cities and the settlement of the nomads. This trend, along with improved medical services, is prompting an increase in localized population pressures with consequent growing demands on the adjacent land resources. To meet these expanding demands, development priorities are directed toward projects that will quickly solve immediate problems. The introduction of Western technology increases expectations of the land's resources while providing no guarantee of sustained high productivity. This only tends to compound the problems of environmental degradation in Chad. Some examples of development projects in Chad that could fit this counterproductive category are animal traction tilling, borehole development, introduction of cash crops, and irrigation projects.

The traditional method of seedbed preparation in Chad is the simple scratching of the soil surface with a hand implement and dropping seed into the depressions. Farmers who see the higher first-year crop yields resulting from animal-traction tilling are easily convinced of its merit. There is, in fact, a firstyear increase in crop yield after plowing (Charrire, 1978), but repeated plow cultivation and loss of perennial root systems leads to a depletion in soil structure and fertility as the fields are made vulnerable to wind erosion and the organic matter is more rapidly oxidized.

Water developments for the benefit of livestock production have had severe effects on the ecosystem in Chad. Additional water allows a growth of herd size and encourages locally intense range retrogression around boreholes (Le Hourou, 1980).

The introduction of cotton as a cash crop into Chad has compounded the problems of resource stress. Much of the suitable cropland is devoted to this "luxury crop," with encouragement from local government. Cotton is now the first crop to be planted on a five-year rotation with millet, sorghum, and peanuts. It requires more fertile soil and it removes more nutrients than the other crops.

The technology of irrigation, with complex pumps that require imported parts and regular servicing, appears out of place in Chad. Without an extensive, easily obtained water supply, irrigation projects tend to build expectations that may be illusory. There are relics of ephemeral irrigation projects that folded soon after the expatriate technician left. The level of technology applied is rarely understood within the cultural context of the Sahelian villager and thus often not maintained by him. This may eventually be regarded, however, as the redeeming virtue of misapplied Western technology in the Sahel: a lack of permanency.

Compounding the problems associated with the application of inappropriate Western technology, agricultural development projects in Chad rarely cooperate with one another for the optimization of resource utilization. Some believe it is a result of interagency jealousy among the host country government offices, or distrust, or lack of communication, or tribalism, or just a basic lack of interest to cooperate at the local ministerial level. These considerations could, and do, impede project coordination, but the technical assistance community is equally at fault for many of the same reasons.

Viewing the problem of desertification in its entirety reveals the prerequisite of balancing resource availability with coordinated resource utilization. This proper use of resources will only be possible when there is cooperation among the various users. The forester, the agronomist, the soil scientist, and the range manager must work together with the farmer and herder to obtain maximum long-term productivity from the land. The question therefore becomes how to organize the foreign technical assistance programs into an ecologically sound unit easily understood and likely to be received by the rural villager.

An innovative rural development project in Chad during the period 1976 to 1979 proposed the application of a popular and easily understood concept of revegetation using the versatile Faidherbia albida tree as a means to focus concern and unify efforts of the various agricultural development groups.

Planting Faidherbia albida on marginal farmlands of the Sahel is not an end in itself. The project was designed also to coordinate development efforts and bridge the communication gap between the technical assistance agent and the villager. As the extension worker learns to understand the cultural constraints of the villager, and as the villager gains confidence in the extension agent, a more complete land management program may evolve that could include all aspects of agricultural and livestock production development.

The final goal is a culturally acceptable, ecologically oriented program for integrated land management. This integrated development approach to ecological stability in the Sahel may be termed an agro-sylvopastoral approach, signifying a unification of efforts. (Agro-sylvo-pastoral is becoming a popular term used in francophone Africa to imply the cooperative development efforts of the agricultural [agro],sylvicultural [sylvo-], and range management [pastoral] disciplines.)

Characteristics of faidherbia albida

Faidherbia albida, or Acacia albida, is referred to in Arabic as the haraz. It is a member of the legume family and of the subfamily Mimosoideae. The species is characterized by bipinnate leaves, orange curled seed pods, cream-colored flowers, and thorns.

Faidherbia albida reaches heights of 3-10 m in 10 years, depending on environmental conditions (Wickens, 1969). It may grow as a shrub if continually grazed (Wickens, 1969), but usually develops into a tree with a large spreading crown. The mean maximum height is 25 m, with a girth of 5 m (United Nations Development Programme and Food and Agriculture Organization of the United Nations, 1968). It is a long-lived species, with an average life span of 70-90 years in the Sudan and known to live more than 150 years in Zambia (Wickens, 1969).

Faidherbia albida has an extensive taproot system that develops rapidly to reach an adequate moisture layer. This characteristic makes the species relatively drought-resistant. On the coarse alluvial sands of the Sudan, a 6-month-old seedling with 8 cm of areal growth had a taproot of 70 cm (Wickens, 1969). A 3-year-old seedling excavated in northern Nigeria produced a taproot in excess of 9.9 m (Weber, 1978).

The most unusual phenological characteristics of the species are retention of the leaves during the dry season and shedding of leaves at the onset of the wet season. No other African savanna species is known to possess this reverse deciduous cycle (Wickens, 1969; Weber, 1978).

In Africa, Faidherbia albida is found wherever there is a long dry season: from southern Algeria to Transvaal and from the Atlantic to the Indian Ocean (Giffard, 1964). It prefers a well-drained sandy soil with a permanent water table, but will also grow on clay soils (Wickens, 1969); Weber (1978) indicates that it may be found anywhere millet can grow. It typically occurs on bush-fallow of cultivated fields or land grazed by livestock, and rarely occurs in natural woodlands that have not been exploited by man. Wickens (1969) suggests that this might indicate that Faidherbia albida is an alien species of uncertain origin.

Natural regeneration of the species is both stimulated and repressed by grazing animals. The seedpods are highly palatable and livestock can distribute the seed 150 km from the source. Ruminant digestive juices stimulate seed germination (Weber, 1978). With increased grazing pressure and more intensive cultivation, however, natural regeneration is becoming more difficult for all perennials of the Sahel, including Faidherbia albida.

Because of its beneficial qualities as an important dry season fodder, source of fiber, a shade tree during the hot period of the year, and a preferred location for crop production (McGahuey and Kirmse, 1977), it is a protected species in many parts of the Sahel (Dancette, 1968).

Blancou et al. (1977) have shown that browse is a very important component of the dry-season diet for cattle in the subtropics, providing the principal source of protein and carotene. Reports of the crude protein content of Faidherbia albida leaves range from 14 percent to 17 percent, and three studies of the chemical composition of pods averaged 12.2 percent crude protein (Wickens, 1969). The highly nutritious and palatable pods and leaves of Faidherbia albida are readily consumed by all domestic and wild herbivores. Nomadic herdsmen typically lop the branches to provide browse for their stock; the seedpods fall to the ground in March and

April during a time of nutrient stress for Sahelian herbivores.

Dense stands of the tree can provide forage equivalent, from pods alone, greater than any other local forage on a per hectare basis (Charreau, 1974; table 12-1). A wood savanna in which Faidherbia albida is the dominant tree species is able to stock 20 animal units per km^2 as compared with 10 animal units when Faidherbia albida is not present (Giffard, 1964).

Extensive research on the soil-enriching properties of Faidherbia albida has been undertaken in Senegal (Charreau and Vidal, 1965; Jung, 1967, 1970; Dancette and Poulain, 1968), and in Niger by Dougain (1960). All soil nutrient properties were observed to be improved by the presence of the species. Increases from 20 percent to 100 percent were found in the nitrogen, available phosphorus, and exchangeable calcium content of the soil (Jung, 1967).

	Total yield per ha	Digestible protein per kg dry weight	Digestible protein per ha	Net energy per kg dry weight	Net energy per ha
Faidherbia albida					
pods	2,500 kg	70 g	175 kg	1,448 Kcal	3,620 Mcal
Peanut foliage	2,000 kg	60 g	725 kg	725 Kcal	2,256 Mcal
Mature native grass	4,000 kg	10 g	40 kg	376 Kcal	1,500 Mcal

Sources: Charreau and Nicou (1971); Boudet and Rivire (1967).

Table 12-1 Fodder Value of Pods of Faidherbia albida Compared with Peanut Tops and Mature Native Grass

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Faidherbia	2,500 kg	70 g	175 kg	1,448	3,620

[illegible] albida pods	[illegible]	[illegible]	[illegible]	[illegible] Kcal	[illegible] Mcal
Peanut foliage	3,000 kg	60 g	725 kg	725 Kcal	2,256 Mcal
Mature native grass	4,000 kg	10 g	40 kg	376 Kcal	1,500 Mcal

Sources: Charreau and Nicou (1971); Boudet and Rivire (1967).

Studies by Dougain (1960) in Niger indicate that on a 10-cm depth basis, which represents about 1,500 tons of soil per hectare, the nutrient increases due to the presence of Faidherbia albida were equivalent to the following amounts of fertilizer amendments per year: 300 kg nitrogen, 31 kg phosphorus as P2O5 and 24 kg magnesium. The tree also served as a windbreak, which protects crops and native vegetation from mechanical damage and excessive transpiration (Dancette, 1968).

Charreau and Vidal (1965) calculated that under Faidherbia albida trees in Senegal, millet production was 2.5 times that of crops grown in the open, and protein content of the grain was up to 4 times greater. Dancette and Poulain (1968) demonstrated that peanut production can be 36.7 percent greater under the influence of Faidherbia albida.

The nutritional benefit of Faidherbia albida to crops grown beneath the canopy is consistent with the "islands of fertility" concept described by Garcia-Moya and McKell (1970) for shrubs and trees in semiarid lands. Woody perennials extract nutrients from deeper layers of the soil profile and deposit them at the surface in litter (Charley, 1972; Fireman and Haywood, 1952; Rickard, 1965). These plants also provide cover for animals and trap wind-borne debris. Soil water retention may be as much as 43 percent higher under the canopy of Faidherbia albida (Charreau and Vidal, 1965). A more favorable moisture and temperature environment will promote microbial decomposition and nutrient release. Since Faidherbia is a legume, symbiotic nitrogen fixation may contribute to the nutrient pool enhancement.

The characteristic reverse deciduous cycle of Faidherbia albida is a key physiological property that allows satisfactory production of crops under a full stand of the species. The leaves are shed at the onset of the rainy season, allowing sunlight acces to the crops and reducing competition for water in marginal croplands.

The wood of the Faidherbia albida tree is hard, and favored locally for the construction of mortars and pestles as well as for other light carpentry uses. Localized uses also include charcoal production and dugout canoe construction. The bark can contain up to 28 percent tannin and is used for treating hides (United Nations Development Programme and Food and Agriculture Organization, 1968).

The above-mentioned multiple use qualities of Faidherbia albida indicate that the species would be of interest to (1) the agronomist for increasing crop production without the use of expensive fertilizers; (2) the livestock producer for fodder during the dry season, as well as for shade; (3) the watershed manager for improvement in soil waterholding capacity and decrease in erosion; (4) the forester for timber uses; and (5) the farmer as an improvement in his living standards without a change in cultural traditions. It is for these considerations that Faidherbia albida can be a focal point of a coordinated agrosylvo-pastoral land management program.

Many authorities on the problem of desertification recommend planting the species as an appropriate land management component in the Sahel (Catinot, 1974; Dancette, 1968; Delwaulle, 1973; Giffard, 1971; Guilloteau, 1953; Weber, 1977). There have been several attempts to organize land management programs using Faidherbia albida - in Niger, Senegal, Nigeria, and Chad. The Chad project is an interesting case study of the possibilities and problems of such a program.

Project description

In June 1976, the Cooperative for American Relief Everywhere (CARE), with funding from the United States Agency for International Development (USAID), set out to try an ecological approach to increase productivity and improve resource management in Chad by the planting and protection of Faidherbia albida trees on marginal farmlands. It was hoped that this popular and visible planting program would serve as a tool that could bridge the gap of communications among the various development agencies and the villages so that an integrated resource management program of a larger and broader nature might develop.

The 3-year project proposed the planting of 100 seedlings of Faidherbia albida per hectare on 3,500 hectares of marginal farmland that was currently under cultivation. One hundred seedlings per hectare is 5 times the number of mature trees recommended by Giffard (1964) as sufficient to-provide continuous cropping without the need of intermittent fallow periods. Because of the expected mortality of seedlings, this high planting intensity was considered necessary to ensure the survival of the desired numbers of trees and their proper distribution.

Cultivated fields, rather than abandoned fallow fields, were targeted for planting for two reasons: (1) to work with and employ the local farmers, following Eckholm's (1976) reasoning that the local inhabitants must willingly participate and recognize their self-benefit before a conservation project will succeed; (2) survival rates are much higher in cultivated fields than fallow land because of the extra protection the farmer provides against fire, grazing pressure, and grass competition (CARE, 1978).

The project area consisted of marginal farmlands just north and south of the 400-mm rainfall belt, which includes the arid fringes of the desert between latitudes 10°N and 13°N, with annual rainfall ranging from less than 200 mm in the north to 700 mm in the south. This area was selected to demonstrate project technology in the most critically affected zone of the desertification phenomenon.

The land was inhabited by various tribes of sedentary farmers and pastoralists including the Sare, Moundan, Fulani, Arabs, Toubouri, Massa, Baguirmi, and Kotoko. Of these only the Sare, Moundan, Toubouri, and Massa had an inherent understanding of the benefits of Faidherbia albida and a tradition of protection and respect for the tree; other tribes have recently settled the area, coming from regions where the tree does not occur. Cultivated crops include millet, sorghum, cotton, and peanuts; livestock in the area include cattle, sheep, goats, and camels.

The program design specified an initial questionnaire to obtain some semblance of understanding of local needs, perceptions, and resource constraints. The survey sampled all locations of the project in order to canvass the various tribes and detect cultural differences.

Time and language constraints rendered this endeavor practically worthless. The project managers, who were from the United States, spoke in French (through a translation to Arabic) to the villagers whose mother tongue was any of a number of local dialects. The translators (French to Arabic) were Chadian Forest Service agents of the ruling class tribe (Sare), which was not trusted by the other groups.

Time was a limiting factor because the project was required to produce tangible evidence of progress before the first rainy season or else lose funding credibility. Therefore, out of necessity, and, it was hoped, in fairness to all tribal members, the program was standardized: one policy for project operation was applied to all participants (at the expense of adjusting to the various cultural differences).

Project Implementation

Nine nursery and extension centers were established in various locations ranging from 150 km north to 250 km south of N'Djamena. Local villagers were hired and trained to run the nursery operations Every effort was made to establish nursery techniques for seedling propagation commensurate with locally obtained materials and indigenous technology.

Approximately 2,500 farmers and their families participated in the revegetation effort. The targeted 3,500 hectares were all planted by the third growing season. An organized campaign was necessary to ensure that all seedlings were in the ground within a two week period at the onset of the rainy season. This planting-out component of the program proved to be clearcut in terms of social and environmental complications, especially in comparison with the truly difficult task of protecting the seedlings in the field after their establishment.

In the first year of operation, 54,000 seedlings were planted on 540 hectares of cropland. Within the next 12 months, there was a mortality rate of 73 percent, resulting in survival of only 14,500 saplings. In the second planting season, 285.500 seedlings were established with 58 percent survival, mainly because of an improved protection program, bringing the total number of saplings after 2 years to 178,000. Oneyear-old plants had a much higher capacity for survival. During the third season (1978), 292,000 seedlings were planted. Combined mortality for seedlings and older plants was to be about 26 percent, leaving 350,000 young plants by the fourth year from the 470,000 cumulative total population.

Among the mortality factors, grazing pressures caused the highest losses. Faidherbia albida is highly palatable to all herbivores, and, being one of the few species with green foliage during the dry season, it was readily taken if not protected. Perimeter fencing of the land was not possible or desired, as this would have disrupted the traditional grazing patterns of the nomadic herder. Furthermore, imported fencing materials that would resist the rigors of the environmental conditions were highly prized by the local villagers and rapidly disappeared. Instead, the laborious task of fencing each individual tree with suitable local materials, such as thorny branches, was undertaken.

Uncontrolled range fires also took a heavy toll of the young seedlings. Convincing the villagers and nomadic herders to refrain from their traditional burning habits was futile. Here again, the only solution proved to be a major task, that of clearing fire lines, 2 m in radius, around every seedling. This clearing of the native grasses also served to remove competition for soil moisture in favor of the Faidherbia seedling.

Where termite infestation occurred, insecticides were applied on a tree-by-tree basis. Fencing material also had to be protected from the ravaging termites by a combination crankcase oil and insecticide treatment. Crankcase oil was more easily obtained and less expensive than commercial wood preservatives.

There were, of course, unfavorable environmental factors completely outside the control of project management. Periodic droughts could not be controlled. The rainy season normally lasts about 2-3 months in this part of Africa, leaving a pronounced dry period the rest of the year. For a seedling to take root before this long dry season, it had to be planted early during the rainy season, but only after the soil was moist to a depth of 40 cm (CARE, 1977). Correct planting time was critical to seedling survival, but unfortunately was highly dependent on luck. If a two-week dry period occurred immediately after the seedling was planted, chances of survival greatly decreased. Another seedling mortality factor beyond control of the project management was damage inflicted by elephants that selected Faidherbia albida saplings as preferred browse (CARE, 1977).

Technology Transfer Problems

In the face of environmental dispositions toward mortality, the predominant influence on seedling survival derived from the interest of the farmer who planted and protected the seedlings on his land, especially his understanding of the purposes of establishing the tree and the benefits it would bring.

In an effort to achieve an adequate level of understanding, an intensive training and sensitization program was initiated. Films were made, talks given, and demonstrations presented. All of the conventional western extension tactics were employed to promote the idea of Faidherbia albida as a key to proper land management. Interest was certainly generated, although not for the reasons one would have wanted. As one CARE employee pointed out, "We are the only show in town."

It was necessary to prop up the extension efforts with an incentive policy to attract the initial participation of local villagers into the revegetation scheme, and to encourage continuous protection of the planted fields. This incentive component involved the distribution of American-donated food commodities (called "food for work"). Some contend that giving food creates a dependency and an expectation by villagers that they must be compensated for their efforts to help themselves. This is a reasonable fear, but project experience demonstrated that satisfactory participation is simply not possible without such food, or some other incentive. (Actually, the Chadian chief of the Forest Service suggested cash payments would be necessary.)

In most cases the village chief (Blahma) or religious head (Sultan) was the instrument of local project administration, which turned out to be a most successful extension arrangement. The ethnic diversity of the area presented insurmountable obstacles for complete coordination of activities. People of different tribes in this part of the Sahel (and probably elsewhere) simply do not work together.

The project was heavily burdened by the traditional problems of incomparability between government extension agents and rural villagers. Government agents tended to assume a patronizing attitude in their extension methods. They were well trained technically, but poorly prepared to communicate ideas to the rural villagers or to motivate farmers to support the idea of the agro-sylvo-pastoral program.

Project analysis and evaluation

Most foreign assistance projects concerned with agricultural or pastoral development in Third World countries operate on assumptions, both technical and sociological. The technological transfer process generally assumes that the technology used in the developed country will work equally well in the client country. Because of critical deficiencies in research and lack of expertise of Western technicians in the Sahelian situation, this assumption is often found to be faulty. A classic example of misapplication of technology is the use of sophisticated machinery in a land remote from spare parts, and among people unaccustomed to engine maintenance. The advantage of the agro-sylvo-pastoral program in Chad is that the "technology" of Faidherbia albida is natural to the Sahel, time-tested, and well studied by research scientists.

Assumptions concerning the social implications of rural development programming in the Sahel are yet more complicated, as they deal with intangible and elusive cultural nuances. It hardly can be expected that a technical expert will fully understand the cultural setting within which he is to operate. In fact, pretensions to understand often lead to the chronic problems of Western ideas being imposed on unwilling villagers. This is not to imply that project personnel should ignore the cultural context; rather, they should be sensitive to the needs of the villagers and include local input into the planning as well as the implementation phases.

The problems of change agents who are unfamiliar with client needs and perceptions, insensitive to different socioeconomic status and the particulars and complexions of different ethnic groups, who presume to know what is best for the client, and assume only temporary involvement in improvement projects, are examined in depth by Mbithi (1974) in a Kenyan context. These are universal issues in rural development, and the Faidherbia albida project was no exception. In the latter case, an idea - an ecological concept with commercial agricultural value was to be imposed on the villagers with the assumption that the local inhabitants understood or could be taught the principles of the program. This proved to be the weakest point of the project. Farmer understanding was critical to the success of the program but yet was based on nothing more than Western hope and expectations. For all practical purposes, there was no effective local planning, and the project had to rely on free food incentives for motivation instead of on the villagers' adoption of program objectives.

From another point of view, transmitting a thorough understanding of the ecology of a Faidherbia albida plantation may have jeopardized the project. Under the traditional cropping system, soil fertility is depleted after about five harvests and the farmer and his family then move on and clear a virgin or recovered field. But it takes Faidherbia albida about 15 years to reach maturity and produce the promised benefits. The cooperative farmers who carefully watched over the seedlings established on their cropland for the CARE program would have to abandon their husbandry 10 years before the fruits of their labor could be fully realized. The trees protected for those four or five years would be able to make it on their own, and the objectives of the project would be reached eventually, possibly at the expense of the original partnership between donor and farmer if the latter did not return to the same field.

The project was a technical success because it reached its goal of planting 3,400 hectares, and involved over 2,000 farmers, plus their families, in the three-year effort. It was also successful in providing a focus to coordinate the interests of various technical assistance groups working in the country.

On a sociological scale, the project could be rated a failure because of the requirement of a food incentive to assure participation. The 15-year delay before plantation benefits are realized cannot be overlooked while evaluating the impact of this project on a people living at a subsistence level. It has been observed that African languages often do not allow for a future tense (Mbit), 1969); this could definitely handicap a project with long-term goals.

It would seem, therefore, that the change agent (in this case CARE) should be required to remain active in the project until benefits can be seen by the recipients, but this condition is generally constrained by the modus operandi of the funding agency. In 1976, USAID, for example, would only fund projects for periods of three years at a time. At the end of each three-year period, continued funding was dependent on proven success, such as increased animal production, increased agricultural output, or increased rural jobs. This project, by nature of the biology of the development tool, required much longer than three years to realize production gains or social changes. For this reason, a program with an ecological orientation such as this is less likely to receive continued financial support compared with irrigation, veterinary services, fertilization, and farm mechanization improvements. or other highly visible projects with short-term objectives.

It is imperative that a project with the far-reaching goals of the Faidherbia albida establishment program continue to be motivated by the extension agent until the clients see the results of their efforts and become willing participants.

Unfortunately, this project did not continue. The reasons, however, had nothing to do with the inherent problems of rural development programs. The sudden and unexpected end of the project was caused by the coup d'tat in Chad in 1979, an event that underlines the ultimate prerequisite for a successful desertification control project - a stable governmental structure within which to work.

Conclusions

The desertification process is a complex web of environmental disturbances, and its control is confounded by a labyrinth of social and ecological complications. "Modernization" has reached a stage in the Sahel such that a return to traditional ways would not be possible, even if desirable, as a means to check the "desert creep." It is in the interest of the developed world to work with the affected countries to find an ecologically sound and socially acceptable solution to the degradation problem. The ecological understanding necessary to apply conservative land management is available, but because of social and cultural differences the framework within which it may be properly applied has not yet been developed.

A suitable framework for development and conservation of the

Sahelian ecosystem must involve a unified effort on the part of all sectors of agricultural and livestock production to ensure proper use of the land's resources. Development efforts in the Sahel, however, do not have a history of such cooperation; coordination of efforts will come only with coordination of interests. The unique multipleuse characteristics of Faidherbia albida, built into a rural development project, could be a device to focus related interests and forge cooperation between development efforts that have obvious ecological connections. This facilitation may ultimately be more helpful to the recipient country than the direct benefit of Faidherbia albida plantations to the agricultural and forage resources of the land.

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Improving Nigeria's animal feed resources: Pastoralists and scientists cooperate in fodder bank research

BY SIMON CHATER

Research on fodder banks in Nigeria's Middle Belt has reached a crucial stage as scientists on the Subhumid Zone Programme of the International Livestock Centre for Africa (ICLA) confront pastoralists adoption problems.*

The pastoralists have mixed feelings about their fodder banks. They say the 4-hectare fields of Stylosanthes are an expensive investment and too small to meet the supplementary feed requirements of all their animals. Yet those who have them are retaining and occasionally expanding them, and the number of fodder banks in the region continues to rise.

More than 70 fodder banks have now been established in Nigeria. During the early stages of the research, establishment costs were borne by ILCA, but now the pastoralists themselves are shouldering the burden. To help them, Nigeria's National Livestock Project Unit is extending credit for fencing, seeds, and fertilizer.

The scientists and pastoralists face complex problems at almost every stage of the establishment and management of the banks.

Potentially, land tenure is the major deterrent to adoption. Secure rights to land for at least five years are necessary for a pastoralist to be willing to invest in a fodder bank. Relationships between the settled Fulani pastoralists and the indigenous farming groups who predate their arrival are at best ambiguous, with farmers tolerating the presence of pastoralists on their land for a number of years before reclaiming it, obliging the Fulani to move on. In response, some pastoralists are currently negotiating to buy land; others have chosen to settle on government grazing reserves. ILCA's scientists are now experimenting with the rotation of food crops within fodder banks so as to take maximum advantage of the improved soil fertility left behind by the legume. They hope their results will encourage farmers to allow pastoralists to use their fallow land.

Meanwhile, unexploited land is the most popular choice for siting fodder banks. Once the site has been secured, the pastoralists' first task is to clear it. Hiring heavy earth-moving machinery to remove all the vegetation is neither practical nor advisable - it is too expensive and can lead to soil erosion. However, some pastoralists have successfully established fodder banks after selective clearing by hand.

Another major deterrent is the cost of metal fencing - around N 2400 (US$2,700) for a 4-hectare fodder bank. Fencing is needed because the transhumant pastoralists who bring their herds through the zone during the dry season do not recognize privately owned grazing resources. Live fences made from local trees and shrubs might be a cheaper solution but are slow to establish. Barbed wire used with poles cut from the bush probably offers the best compromise. The cheaper the form of fencing the better, since the pastoralist is likely to get little compensation for his investment when the farmer reclaims his land.

Once fenced, the land must be cultivated. The method first tried by the scientists was to get the animals to do the work by trampling a seedbed during the dry season, leaving a heavy deposit of manure. This proved effective, but was unacceptable to some pastoralists because their herds were needed to manure cropland during this period. A second method now under test involves trampling in the early wet season, once food crops have been planted, and grazing after the stylo is sown. The choice of methods allows the pastoralist to select whichever one is best suited to his circumstances.

The availability and quality of legume seed are further problems.

At present, only three Stylosanthes cultivars are commercially available in Nigeria, and two of them are dangerously susceptible to the fungal disease anthracrose, which can wipe out entire stands of the legume. A wider range of resistant varieties is needed, and ILCA is carrying out screening trials in order to select these.

Seed is prohibitively expensive (US$13.5 per kg) and its quality is low. Up to 60 percent of a kilo of Seeds" may in fact consist of sand.

Mixed in with the legume seeds are those of weeds that when planted may flourish at the expense of the legume. Traditionally, women who collect seeds are paid by the weight they hand in rather than the time they spend gathering and winnowing. Buyers will have to exert tighter quality control if the high seeding rates (8-10 kg per hectare) currently needed to start a fodder bank are to be reduced.

During the growing season, animals eat young nutritious grasses in preference to legumes. In theory, this behavior can be used to control grass growth on the fodder bank, allowing the legume to establish. But in practice the timing of grazing is critical, since animals do not distinguish grasses from legumes until at least four weeks after the start of the rains. After this, they will graze grasses only while these are still taller than the legume. Thus, if the legume is to flourish, animal behavior and vegetation growth must both be closely watched to identify the right moment to take the animals off the bank.

Once the rains stop and vegetation dries out, fire becomes a threat. During each of the five years of ILCA's research, entire stands of legumes have been destroyed as bush fires, started accidentally or on purpose, have got out of control.

Predictably, the pastoralists have their own ideas about how their fodder banks should be used. These ideas came to light during the extension phase of the research, and ILCA's scientists are now adapting their component research to take them into account.

Originally, ILCA recommended that the Fulani graze only their lactating and pregnant cows on the fodder banks, in the hope of increasing both milk and calf production. But the pastoralists tend to graze additional animals - often their entire herds - aiming to maximize the welfare of all animals. The scientists are now studying the effects of these heavy stocking levels on herd performance and legume regeneration. One encouraging finding is that the heavy seeding annual S. hamata appears to cope well with both fire and overgrazing.

Fodder banks still need further refinement and testing, but the intervention is receiving encouraging support from both producers and extension workers. On cautious estimates, a (hectare bank would repay its establishment costs in 2-3 years, simply by saving nutritionally stressed animals. Given the additional benefits of greater soil fertility and faster herd growth - leading to more offtake - the prospects for increased adoption still look good.