Natural Habitats and Ecosystems Management in Drylands: An Overview

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Dryland ecosystems have provided many of the plant and animal species that have shaped the development of many cultures and civilizations. Crop species such as wheat, barley, sorghum, millet and cotton have all originated from dryland ecosystems as did animal species such as the horse, the sheep, the goat, the cow, the camel and the lama. However, human-induced environmental degradation now threatens the ecosystems and the natural resource base in many of the world’s dryland areas and more than 900 million people in 100 countries are affected, to a greater or lesser degree. Whether or not degradation will prove catastrophic in the future depends upon the willingness and ability of countries to adopt environmentally sustainable development practices that can help end the vicious cycle of poverty, population growth, and resource degradation characteristic of so many dryland areas. This publication provides an overview of key strategies to meet that challenge. It gives examples of good practices in land management in dryland areas without being prescriptive.

Characteristics of Dryland Regions and Significance of their Biodiversity

The defining feature of dryland climates is the low average rainfall and the variability in rainfall patterns. Both of these features substantially limit the opportunities for plant growth and the productive capacity of the land and increase the risk of crop failure, livestock losses, and resource degradation. Defined as regions where annual potential evaporation and plant transpiration exceed annual precipitation, drylands constitute about 40 percent of the world’s land area and they may be divided into four climatic zones: hyperarid, arid, semiarid, and dry subhumid. Hyperarid regions compose the true climatic deserts, such as the Sahara, Atacama, and Namib deserts. Here irrigation is practiced in oases, fed by rivers rising in the humid regions and by fossil groundwater. Arid regions are almost exclusively used for extensive grazing. Semi-arid lands are largely pastoral, but include extensive rainfed cropping in the wetter parts. Dry subhumid zones are woodlands and forested lands where intensive cropping is practiced, along with livestock production.

Dryland soils are frequently characterized by low fertility, associated with low levels of organic matter and nitrogen. However, water deficiency is the principal limiting factor in plant growth with vegetative cover varying from forests in the dry subhumid zone to virtually nothing in the hyperarid zone except in stream channels. In the arid and semi-arid zones, vegetation tends to be patchy and to vary widely in productivity from year to year. In the absence of excessive human disturbance, dryland vegetation has good resilience often recovering rapidly from the droughts and fires.

Dryland ecosystems support a wide variety of plants and animals which frequently exhibit wide genetic variation within species due to the selection pressure brought about
by the harsh nature and variability of the dryland environment. The species are sometimes abundant and unique, surveys of the distribution of mammal taxa in South America's six major macrohabitats indicate that when endemics are endangered drylands are the richest area in numbers of species supported and are more diverse than other habitats, including the lowland Amazon rainforest.

Globally, there are a number of dryland areas that have particularly high plant species diversity. These include the Cape and Karoo-Namib Regional Centres of Plant Endemism in Southern Africa and the South-West Botanical Province of Western Australia. Moreover, wetlands within drylands (for example, the Hadeja-Nguru in Nigeria, the El Kala region in Algeria, and Cuatro Cienegas in Mexico) serve as both indispensable nesting, resting, and breeding grounds for important migratory species and key resources for human survival in dryland environments.

As a result of selection pressures, dryland species exhibit a wide range of morphological, physical, and chemical adaptations to their harsh environment. This makes them a vital source of genetic material to improve crop tolerance to drought and disease as many of the plant and animal species that have helped facilitate the development of human civilization have come from dryland ecosystems.

Habitat Degradation in Drylands

The major degradation processes in drylands are vegetation degradation, water erosion, wind erosion, salinization, and soil compaction. The incidence and type of degradation varies considerably across different land uses (for example, grazing, rainfed cropping, and irrigated agriculture). Based on rough estimates, approximately three-fourths of arid rangelands are at least moderately degraded, compared with one-half of rainfed croplands and one-third of irrigated land.

Degradation of rangelands is primarily associated with loss of vegetative cover, degradation of rainfed croplands with water and wind erosion, and degradation of irrigated croplands with salinization. This is often accompanied by soil erosion and is thus a direct threat to dryland ecosystems and the natural habitats they form with plants and animals. Crops, whether rainfed or irrigated, completely replace the natural ecosystem and, if soil degradation occurs, can potentially destroy ecosystem functionality.

Natural habitats and ecosystem management endeavors to secure both the conservation of biodiversity and the maintenance of ecosystem functions needed to maintain productivity and environmental services to meet human needs.

Factors that Encourage Unsustainable Land-Use Practices

Dryland ecosystems have significant environmental constraints that are associated with their aridity, rainfall variability and low soil fertility. As water is often the first limiting factor on biological productivity, dryland ecosystems have relatively marginal suitability for human occupation and use. This low resource capability is often exacerbated by unsustainable land use practices resulting from both pressure and institutional factors.

Pressure factors are those that directly influence the demand and supply for natural resources such as population growth and consumption patterns. Institutional and social factors determine the extent to which pressure factors are well managed. They include patterns of laws, policies and tenurial and organizational arrangements that ultimately shape both societal and household decisionmaking and resource utilization.
patterns. These also include the international and national policy environments which determine the incentive structure for sustainable land use, the institutional capacity for facilitating environmental management, and the economic conditions that influence availability of private and public financial resources to invest in land management.

Several factors are frequently combined to limit production and increase land degradation. The cycle of poverty, poor education, lack of capital to invest in improved technologies, and land degradation is difficult to break. Pressure and institutional factors frequently tilt decisionmaking toward short-term goals, away from the long-term necessary for resource conservation and devising and carrying out sustainable land use practices.

Alternative strategies need to favor the development of diverse land management systems capable of adapting to the variability of seasonal and annual rainfall patterns. Such systems may consist of various combinations of livestock production, wildlife management, commercial hunting, tourism, runoff farming, poultry/rabbit production and nonagricultural activities, such as handicrafts. In areas with appropriate land capability, intensification can be a substitute for new land clearing, potentially lowering the risk of land degradation while increasing production. However, in the face of rural population growth, land use practices frequently involve agricultural expansion into drier, more marginal lands, often converting formerly good grazing land into poor cropland. Similarly, unplanned urban population growth frequently results in urbanization of good cropland, thereby reducing the resource base upon which growing rural and urban populations depend.

Rural development has become increasingly dependent on both the national and the international policy environments. In a market economy, policies formulated in national capitals or in far-off countries can determine whether a farmer plants cotton for export or sorghum for national consumption. Additionally, many social issues influence the sustainability of rural economies. Lack of land tenure security and breakdown of traditional forms of local governance can exacerbate income inequalities and land degradation. Closing state lands to users may protect endangered species but cause food shortages in adjoining communities. Marginalization of rural women further exacerbates the misapplication of household resources and deterioration of the resource base. Lack of capital assets, limited access to financial services and markets, ineffective advisory services, and ineffective safety nets in times of stress are common factors that limit choices. Another major factor influencing future agricultural productivity is the apparent non-profitability (particularly in the short-term) of some soil and water conservation practices. Where these conservation investments do not bring significant immediate increases in crop yields, few farmers are able or willing to forego current production in return for future yields.

**Traditional Coping Strategies**

Traditionally, human populations in drylands have devised and adopted sustainable methods to manage resources and minimize risk to livelihoods under conditions of high variability and uncertainty. Pastoralists became mobile and diversified their livestock holdings; farmers undertook shifting cultivation and used more drought resistant seeds; and communities adopted population control measures. These adaptations are successful as long as populations are low and the land is not significantly degraded. However, pressures have escalated in the past
several decades and new approaches are often needed.

Management Lessons and General Recommendations

Dryland areas pose unique and formidable challenges to sustainable resource management because they are associated with naturally low carrying capacities and high degrees of climatic variability and consequent uncertainty. Dryland management interventions must therefore seek to balance the supply and demand factors that shape resource use patterns, by enhancing the carrying capacity of dryland ecosystems (supply) and encouraging the efficient use and conservation of existing resources (demand). Two characteristics of effective interventions are particularly important—an emphasis on an "ecosystems approach" that considers the interactions between resource users and the full range of natural resources that comprise ecosystems, and an "adaptive approach" that can readily respond to changing conditions in the face of uncertainty. The over-arching objectives should be the conservation of the natural resource base and improved welfare of people directly dependent on dryland resources.

The processes that govern the sustainability of land use in dryland areas encompass a complex network of interactions between international, national and local levels. Accordingly, the solutions have to be multifaceted, but focused on influencing household and community decisions regarding investments in productivity and conservation both on and off farm lands. Management objectives in dryland regions include sustainable agriculture development, poverty alleviation, and environmental conservation. Macro- and micro-economic policy instruments should aim to provide incentives to households to use dryland resources optimally. This implies management of pressure factors (population growth, migration, environmental constraints, and natural disasters) in combination with reform of disabling institutional factors (national and international economic policies, institutional distortions, political conflicts, and poverty).

With the above in mind, projects and programs are more likely to succeed if they are designed in a flexible yet integrated fashion and include the following elements:

- Strengthening of information and monitoring systems, especially to improve drought preparedness
- Development of integrated programs and policies based upon an ecosystems approach to dryland resource management which adequately balances conservation and production objectives
- Improvement of dryland resource management through environmentally sustainable practice
- Development of programs to eradicate poverty and promote alternative livelihood systems
- Support for indigenous technologies and local participation, and
- Support for control of population growth rates.

Dryland management strategies need to be flexible, adaptive, and responsive to feedback, particularly in view of the changing resource constraints associated with the unique conditions of dryland regions. Special risk-management strategies are required, such as early-warning systems to alert land users and management to impending crises and help mitigate the effects of drought. Management programs have to be sensitive to the cultural and social milieu within which they are implemented. Consequently, key stakeholders must perceive and enjoy the benefits of interventions to ensure their cooperation and increase the chances of
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success. This requires full community participation in development planning and management.

Endnote

1. Further sector-specific information is available from several related World Bank publications, including “Mainstreaming Biodiversity in Agriculture Development: Toward Good Practice” (Pagiola and Kellenberg 1996); “Best Practices in Natural Resource Management: Guidelines for Pastoral Development in the Middle East and Africa” (Pratt, Le Gall, and de Haan 1996); “Carrying Capacity—Sustainable Use and Demographic Determinants of Natural Habitats and Ecosystems Management” (Grimble 1996); and the forthcoming Natural Habitats and Ecosystems Management Handbook Working Papers on livestock, forestry, agriculture, water resources, and the social and ecological dimensions of sustainable resource management.
1 Introduction

Natural habitats and ecosystems management in dryland regions is a pressing issue, with more than 900 million people in 100 countries dependent upon the resource base (World Bank 1994). Dryland countries include, but are not limited to, India, Afghanistan, Pakistan, Iran, Syria, China, Argentina, Brazil, Mexico, Peru, Chile, Australia, the United States, Canada, Uzbekistan, Kazakhstan and much of Sub-Saharan Africa.

The Sahelian drought of late 1960s and early 1970s drew attention to the issue of natural resource management in dryland areas, where productivity is typically inhibited by the lack or variability of rainfall (UNCOD 1977). Poor management of natural resources in these areas has resulted in massive land degradation, which in turn has diminished the land’s naturally low carrying capacity for human and animal populations. Moreover, there is some evidence that land surface changes—which include changes in albedo, evapotranspiration, soil moisture, surface temperature and roughness, and dust generation, can prolong and intensify Sahelian drought by reinforcing the atmospheric conditions which initially reduce rainfall (Nicholson 1989 in Cleaver and Schreiber 1994).

In Sub-Saharan Africa, as in most dryland areas of the developing world, environmental degradation, poor agricultural performance, and low levels of economic development are closely linked with “pressure factors” such as population growth, migration and poverty; and with disabling “institutional factors” such as distortionary government policies, market failures, lack of institutional capacity, and political conflicts (Cleaver and Schreiber 1994, World Bank 1995, IFAD 1993). Disabling institutional factors are also an indication of pressure factors being mismanaged, inducing problems such as the degradation of natural habitats and the loss of ecosystem functionality through agents such as deforestation, soil erosion and water-resource depletion.

Ideally, sustainable development policies should aim to create an economic surplus for environmental resource conservation and provide the economic basis for the demographic transition to lower fertility rates (Cleaver and Schreiber 1994). To do this, policies need to focus on both the supply and demand sides of the resource equation. On the supply side, efforts should be made to develop and deliver technology and services that improve the natural resource base. On the demand side, environmentally benign technologies, sound resource management practices, and measures to control population growth should be implemented to facilitate sustainable consumption patterns.

This paper provides an overview of the policies and practices that need to be followed to ensure the conservation of natural habitats and the sustainable management of dryland ecosystems. This section describes the properties of dryland areas which pose special challenges to

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1
maintaining the productivity and ecological integrity of dryland resources. Section II discusses the major causes of environmental degradation in dryland regions and some of the traditional coping strategies. Section III outlines lessons from experience and Section IV has general recommendations for improving natural habitats and ecosystems management in dryland environments.

Definitions of Dryland Regions

Drylands are characterized by a deficiency of precipitation, prolonged periods of heat, low relative humidity, and high rates of evaporation. Drylands constitute about 40 percent of global land surfaces and are home to more than 900 million people.

There is no universally accepted definition of drylands nor agreement on the delineation of the boundaries of dryland areas. Climatologists have been wrestling with this problem for a long time. At first, precipitation was the preferred criterion, although opinions differed over the correct limit. Later, combinations of precipitation and temperature were proposed, as well as various formulas that included relative humidity and evaporation. Since the 1950s, the ratio of precipitation to potential evaporation (P/PET) has been generally accepted as the most suitable criterion (see the appendix for a more detailed discussion).

Currently, the most widely used map of the world's drylands is published by the United Nations Educational, Scientific, and Cultural Organization (UNESCO 1979); figure 1 is a simplified adaptation. Four aridity classes are recognized on the UNESCO map: hyperarid, arid, semiarid, and subhumid (now called dry subhumid). Climatic deserts such as the Sahara, Atacama (Chile), and Taklimakan (China) are examples of the...
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hyperarid zone. This zone has the lowest P/PET ratio, and little to no vegetation exists except along the banks of intermittent streams. The arid zone is characterized by sparse vegetation, and land is principally used for grazing. The semiarid zone supports grazing as the dominant land-use in the drier parts, as well as rainfed cropping in the wetter parts. In the dry subhumid zone, both rainfed cropping and livestock husbandry are successful most years. The lines of demarcation between the climatic zones are not sharp, reflecting gradual transitions. Annual plant production varies widely due to rainfall variations, as depicted in figure 2.

Characteristics of Drylands

The characteristics of dryland ecosystems are described in some detail in the Appendix. However, the over-riding feature of dryland climates is the low average rainfall and the variability in rainfall patterns, both of which substantially limit the productive capacity of the land and increase the risk of crop failure, livestock losses and resource degradation.

Droughts are a normal feature of dryland climates. Indeed, both the frequency of droughts and the spatial and temporal variability of rainfall increases as the climate becomes drier. It is not unusual to have one

Figure 2
Relation of Mean Annual Rainfall to Above-Ground Plant Production

Source: Adapted from Le Houérou 1984.
area experience a drought while only a few kilometers away the rainfall may be enough to produce typical crop yields. Droughts can last for a few months or persist for several consecutive years. One drought year may be tolerable for farmers; but two or three consecutive years of drought are almost always catastrophic.

Indigenous plants and animals living in arid regions have adapted themselves in a number of ways to the harsh climate and frequent drought conditions. As a consequence, dryland ecosystems tend to be quite stable over long periods of time, but plant and animal populations may vary greatly in number and mass from season to season and year to year, due to local weather fluctuations. Human impacts, such as deforestation and other forms of vegetation disturbance, can degrade the productive capacity of resources and cause irreversible damage. Cultivation is one of the most common and extreme human interventions and inevitably destroys the natural ecosystem it replaces; however, by itself it does not necessarily undermine the long-term productivity of the land.

Dryland soils have several characteristics in common, but exhibit major differences between hyperarid and dry subhumid regions. Their common properties include relatively low fertility (principally associated with low organic matter), alkaline, calcium carbonate in the subsoil, sandy or gravelly in uplands, and clayey in depressions. Salinization is a problem in closed basins because the lack of surface water outflow allows salts to accumulate. Human impacts also contribute to salinization, which effects an estimated 25 to 30 percent of irrigated land.

In summary, drylands are characterized by a deficiency of moisture at some time during the growing season, average temperatures that vary from cold to hot, annual precipitation that is less than 75 percent of the annual potential evapotranspiration, highly variable rainfall in the drier part of the dryland zone, droughts that are a normal part of the climate pattern, potential crop production and animal carrying capacity that becomes progressively more precarious as one goes from the subhumid zone to the hyperarid zone, (in the absence of irrigation), vegetative cover changes from nearly closed forests to savannah to woodlands to grasslands to shrublands to barren landscapes as aridity increases, and recovery from vegetation disturbance that becomes slower as annual rainfall decreases. Vegetation composition and productivity seldom reach a steady-state in the drylands, and temporal and spatial variability is greater as the climate becomes more arid with the difference between a more resilient annual vegetation compared to a more vulnerable perennial vegetation. Although natural events such as fire and drought make instability in ecosystems the rule, they do not usually adversely affect the persistence of plant and animal communities. Human interventions are more likely to cause irreversible changes in ecosystems (at least in the time-frame of a human life), mostly in a negative sense but sometimes positive as indicated by the US rangeland study by the General Accounting Office).

**The Biological Significance of Drylands**

Climate has a pronounced controlling effect on biological diversity in the drylands. Dry subhumid regions can have rich biodiversity in regards to both species numbers and within-species variations. In contrast, living organisms may be virtually nonexistent at all trophic levels under the more extreme conditions found in hyperarid regions, from soil microorganisms to reptiles and higher plants.

Dryland ecosystems support a wide variety of plants and animals and these plants and
animals frequently exhibit wide genetic variation within species due to the selection pressure brought about by the harsh nature and variability of the dryland environment (for example, the Mediterranean climate of central Chile supports approximately 1,500 species in an area of less than 100,000 square kilometers). MacMahon (1981) argues that biotic diversity in dryland areas is comparable to diversity in temperate forests, although many others argue that the richness of species declines with increased aridity, and that there is a positive correlation between species richness and rainfall. Regardless, it is apparent that many dryland areas are home to many species, some of which are quite abundant and unique. Indeed, surveys of the distribution of mammal taxa in South America's six major macrohabitats indicate that drylands are the richest area in numbers of species supported and are more diverse than other habitats, including the lowland Amazon rainforest, when endemics are considered (Mares 1992).

Globally, there are a number of dryland areas that have particularly high plant species diversity. These include the Cape and Karoo-Namib Regional Centres of Plant Endemism in Southern Africa (Davis and others 1994) and the South-West Botanical Province of Western Australia (Davis and others 1995). Moreover, wetlands within drylands (for example, the Hadeja-Nguru in Nigeria, the El Kala region in Algeria, and Cuatro Cienegas in Mexico) serve as both indispensable nesting, resting, and breeding grounds for important migratory species and key resources for human survival in dryland environments (Scones 1991).

Dryland plants have evolved in ways that enable them to survive under drought conditions, and exhibit a wide range of morphological, physical, and chemical adaptations to their harsh environments. Some are drought-enduring (such as cacti) whereas others are drought-avoiding (for example, annual grasses). Similarly, grazing animals adapt to climatic variability by migrating over hundreds of kilometers to take advantage of the seasonality and spatial variability in rainfall, and the resulting variation in forage production (Dixon and others 1989). With this adaptability, dryland ecosystems display high levels of resilience that allows them to maintain a reasonably consistent species composition over periods of decades, though population levels can vary considerably in the short-term due to environmental shocks.

As a result of these conditions, dryland species exhibit a wide range of morphological, physical, and chemical adaptations to their harsh environment. This makes them a vital source of genetic material to improve crop tolerance to drought and disease, since many of the plant and animal species that have helped facilitate the development of human civilization have come from dryland ecosystems. Crop species such as wheat, barley, sorghum, millet, and cotton have all originated from dryland ecosystems as did animal species such as the horse, the sheep, the goat, the cow, the camel, and the lama (Bie and Imevbore 1994). A disproportionate number of dryland species in the Egypt's southeastern desert have been found to have immediate economic value to humans (Belal and Springuel 1996) while other surveys have indicated that sixty-four species out of 300 tropical medicinal plants originated in dryland areas (IPED 1995, Bie and Imevbore 1994).
Degradation of dryland ecosystems consists primarily of loss of vegetative cover, water and wind erosion, salinization, waterlogging, soil compaction and crusting, loss of organic matter, soil acidification, and pesticide and heavy metal accumulation (Woods 1983, Science Council 1986, Abrol and Sehgal 1994, Zachar 1982, Mainguet 1991, Buffington and Herbel 1965, Breman and de Wit 1983, McQueen 1992, GAO 1991, Le Houérou and Boulos 1991, Oldeman and others 1990, and Dregne 1992). The consequences of degradation are reduced productivity (carrying capacity), loss of environmental services (for example, watershed management and climate control), and/or loss of biodiversity. This section briefly traces the history of international efforts to reach consensus on the definition and extent of dryland degradation (“desertification”) and the implications for natural habitats. It also outlines the factors that influence degradation processes and discusses the limits of traditional management methods in maintaining dryland resources.

Land Degradation (Desertification)

Land degradation, as a threat to human and livestock survival, was forcefully brought to public attention by the 1969-73 drought in the Sahel. It led directly to the deaths of tens of thousands of livestock and indirectly to human deaths. The prolonged drought prompted the United Nations to convene the U.N. Conference on Desertification in Nairobi, Kenya in 1977. The initial focus of preparations for the conference was drought; however, at the conference it became clear that drought is a normal occurrence in the drylands. Land degradation, frequently exacerbated by droughts, is the long-term problem. Although attention was initially focused on vegetation degradation in rangelands, a consensus emerged that water erosion, wind erosion, and soil salinization are at least as critical. Consequently, desertification became broadly defined as land degradation in dryland ecosystems: “the diminution or destruction of the biological potential of the land, leading ultimately to desert-like conditions” (UNCOD 1977).

Many definitions of desertification have been proposed since the Nairobi conference; most are a variation of the official conference definition. Some state that desertification consists of vegetation degradation on rangelands caused by overgrazing and tree-cutting. Others limit it to wind erosion. A few define it as climate change toward greater aridity. A considerable number of writers and researchers contend that desertification refers solely to the extreme condition of desert wasteland formation (Mainguet 1991). For the latter, there is no moderate desertification, only the very severe degradation that makes land useless for human occupancy. Since very little land has become totally barren wasteland due to human activity, desertification would seem an insignificant problem under this catastrophic definition. The latest, internationally negotiated definition of desertification was adopted at the 1992 U.N.
Conference on Environment and Development (UNCED) in Rio de Janeiro: "land degradation in arid, semi-arid, and dry subhumid areas resulting from various factors, including climatic variations and human activities."

Currently, there is much disagreement about rangeland degradation. Le Houérou (1991) has long maintained, based on extensive observations in nearly all of Africa north of the equator as well as in China and the former Soviet Union, that most rangelands in developing countries with high population densities (relative to the resource base) are moderately to severely degraded. A similar conclusion was reached by Dregne and Chou (1992) in their assessments of the world's drylands (see table 1). In contrast, a number of observers contend that desertification is a "myth" or at least not supported by facts, where much research is needed to prove it (Nelson 1988).

Noting these conflicting views, Lusigi and English (1991) point out that assessing the current status of rangeland degradation poses a major problem. One of the principle difficulties arises from the year-to-year climatic changes that can be extreme. Rangelands may appear to be badly degraded during droughts but covered with lush vegetation during wet periods. Sahel rangelands, and the livestock foraging on them, appear to be in a very poor state by the end of the annual nine or ten-month dry period, then revive almost miraculously when the summer rains are good. Only a multi-year observation period can tell whether degradation is real or apparent.

There are three major commercial land uses in the drylands: livestock grazing in rangelands, rainfed cropping, and irrigated cropping. Degradation in rangelands is of particular concern, because rangelands encompass the vast majority of the world's dryland areas (88 percent) and degradation is far more pervasive in rangelands than under the other land-use regimes. Roughly three-quarters of rangelands are degraded, compared to roughly half of rainfed croplands and one third of irrigated lands (degradation is defined as a 10 percent or

Table 1. Global desertification in drylands
(percent of dryland area degraded, by continent and land-use)

<table>
<thead>
<tr>
<th>Continent</th>
<th>Irrigated land</th>
<th>Rainfed cropland</th>
<th>Rangeland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>18</td>
<td>61</td>
<td>74</td>
</tr>
<tr>
<td>Asia</td>
<td>35</td>
<td>56</td>
<td>76</td>
</tr>
<tr>
<td>Australia and New Zealand</td>
<td>13</td>
<td>34</td>
<td>55</td>
</tr>
<tr>
<td>Europe</td>
<td>16</td>
<td>54</td>
<td>72</td>
</tr>
<tr>
<td>North America</td>
<td>28</td>
<td>16</td>
<td>85</td>
</tr>
<tr>
<td>South America</td>
<td>17</td>
<td>31</td>
<td>76</td>
</tr>
<tr>
<td>Average</td>
<td>30</td>
<td>47</td>
<td>73</td>
</tr>
<tr>
<td>Percent of the World's total dryland area in each land-use class</td>
<td>3</td>
<td>9</td>
<td>88</td>
</tr>
</tbody>
</table>

more loss in productivity, refer to table 1). However, it is estimated that less than 0.1 percent of degraded land is irreversibly degraded (Dregne and Chou 1992).

**Current Status of Dryland Biodiversity**

With growing populations and pressures for development, the biodiversity of dryland ecosystems is under significant stress in many parts of the world, threatening the food security and life support systems for close to 1 billion people who live in dryland areas (Bie and Imevbore 1994). In Central Asia, rapid changes in land use over the last few decades have seen the large scale cultivation of grazing lands, intensive and often poorly managed irrigation, increased exploitation of grazing lands by livestock, increased pressures on fuelwood resources and increased demands for medicinal and wild food plants (Kharin 1994). Similar pressures on dryland ecosystems have occurred in China with a rapid reduction in the area of dry woodland in provinces such as Xinjiang and the consequent loss of habitat for woodland plant and animal species (Lixian 1994). Deforestation and agricultural expansion in Gansu Province have altered hydrological conditions leading to increased soil erosion and sediment loads in rivers used for irrigation. Growing population pressure in China has also increased the demands for medicinal plants.

In South Asia, the major threats to biodiversity come from the rapidly growing human population and the consequent increase in the area of intensely used crop land, the excessive demands for timber products and poorly managed irrigation systems that have led to the loss of significant areas due to salinization, alkalization and waterlogging (Harsh 1994). The drylands of India once contained a rich fauna but many notable species have now disappeared or under threat of extinction (for example, the lion, cheetah, wolf, desert fox and desert hare). However, despite these pressures, concern for wild foods, medicinal plants and certain types of preferred tree species in the general population has led to the development of traditional resource management that has secured the effective conservation of many of these species in many areas. Thus, both India and Pakistan have been able to maintain high levels of genetic variability in traditional food crops in spite of the introduction of genetically improved varieties of dryland crop species.

Biodiversity in Northern Africa is under severe threat due to changes in land use in both recent and historical times (Le Houérou 1994). The drylands of this region occupy an area similar in size to the continental United States or Australia and still contain some 6,000 species of flowering plants with relatively high levels of endemism in both the far east and west of the region. Many large mammal species have become regionally extinct in the last 150 years or so though more than 100 small mammal species, 200 resident bird species and 80 known reptile species still exist. The region is coming under increased human population pressure and has high rates of deforestation (0.5-1.0 percent) in situations of relative forest cover. Severe land degradation is further reducing the capacity of the landscape to support biodiversity.

In the Sahel, approximately 100 million people depend directly on the primary productivity potential of the area and, with rapidly increasing human populations, pressure on these systems and the biodiversity they support is growing (Daoulé Diallo 1994). While the flora of this region has relatively low species diversity, the genetic diversity of these species is known to be high with considerable resilience in relation to the periodic droughts and fire disturbances that affect the region. Nevertheless, increasing population pressures and cyclical drought stresses have
led to serious reductions in regional animal populations. Similar pressures exist in the countries of the Horn of Africa and reductions in both beta and gamma diversity have been recorded in the last several decades (Ottichilo 1994). Additional problems for the biodiversity of this region have arisen from civil strife and the breakdown of law and order. These factors combined with the ready availability of firearms have contributed to increased poaching of wild animal populations.

In southern Africa, both plant and large mammal diversity is well described though few studies have examined the relationships between biodiversity and ecosystem functionality (Cotterill 1994). Most of these areas have low potential for agriculture and have traditionally supported only low human population densities typified by nomadic lifestyles. However, over the last several decades human communities in these areas have begun to live in permanent settlements that are dependent on agriculture. As a result, southern Africa is experiencing rapid changes in land use that are threatening the ecological integrity of many areas. Nevertheless, large mammal populations have considerable economic significance for tourism, game ranching and safari hunting, and innovative wildlife management programs in communal areas through the CAMPFIRE program in Zimbabwe and similar programs in other countries. In some instances, these programs provide economically viable alternatives to conventional agriculture and lead to much improved biodiversity outcomes.

The drylands of Latin America cover a number of smaller regions that cover extensive areas in Mexico, northeastern Brazil, Peru, Bolivia, Chile, Argentina and the Caribbean coast of Colombia and Venezuela. These dryland areas are often separated by some of the more humid regions on Earth. The areas frequently have high levels of endemism and, as noted previously, have higher levels of mammal diversity than some of the surrounding humid forest areas (Mares 1992). A number of these dryland ecosystems also emerged in the highest conservation priority categories in the recently completed Bank review of the Conservation status of Latin American Ecoregions (Dinerstein and others 1995). Agriculture developed thousands of years ago in these regions and was frequently based on species from the borders of the drylands and neighboring more humid regions (Weber 1994). Thus, Latin American drylands contain wild relatives of many agriculturally important plant and animal species including maize, beans, tomatoes, potatoes, llamas and its alpaca.

Some 15 million people live as smallholders in Latin American drylands and the dry northeast of Brazil supports a population of more than 20 million people. Traditional agriculture does not seem to have had a significant impact on biodiversity. However, the extension of irrigated agriculture and dryland timber plantations is causing local concerns, as is the unregulated collection of rare and endangered plants such as cacti. Coastal tourism is also having impacts on ecosystems with restricted distributions in areas such as the Pacific coasts of Mexico and central Chile.

The conservation values of Latin American drylands have not received the same degree of recognition as the perhaps more charismatic tropical rainforests in the region. However, the region has several research institutions dealing with the biodiversity of domesticated crops. In situ conservation is also centered in a growing network of parks and reserves and, in countries such as Peru and Bolivia, in strong local community conservation organizations.

In addition to the above, a number of important dryland areas occur in developed
countries like Australia (Pickup and others 1994), the United States (Hutchinson 1994) and Southern Europe (Mendizábal 1994). These areas have suffered many of the same problems being experienced in developing country dryland with unsustainable extensions of agriculture, salinization, overgrazing, changes to prevailing fire regimes and the introduction of exotic plants and animals. Moreover, extensive urbanization has created a range of problems particularly in coastal areas that include ecological communities with restricted distributions. In the United States, for instance, large scale water transfers to support conurbations such as the greater Los Angeles area have had a serious impact on natural habitats and ecosystem functionality in areas well removed from the city itself.

Factors that Encourage Unsustainable Land-Use Practices

Unsustainable land-use practices which result in habitat and land degradation in dryland areas can be classified under a number of broad categories, including expansion of rainfed cultivation onto unsuitable lands; soil mining and shortening of fallow periods; overgrazing and woodcutting; groundwater mining; and uncontrolled harvesting of biomass (IFAD 1993). These land-use practices are, at least partly, a response to high variability in climatic conditions that can lead to a high incidence of natural disasters. Drylands, by definition, have relatively low rainfall. In addition, total precipitation tends to be more erratic from year to year and more spatially variable than in humid regions. The characteristics of the biophysical environment that limit its carrying capacity, capability and suitability to support human activities.

* Environmental constraints are characteristics of the biophysical environment that limit its carrying capacity, capability and suitability to support human activities.

* Pressure factors that directly effect the supply and demand for resources, and include population growth, migration and natural disasters.

* Institutional and social factors that determine how well pressure factors are managed, that is, in terms of resource conservation and sustainable management they can be both enabling and disabling. They are triggered by the international and national policy environments, institutional capacities and factors such as poverty and political conflict. Disabling institutional and social factors include lack of capital assets, ill-defined property rights, limited access to financial services and markets, inadequate safety nets in time of stress, and lack of participatory mechanisms for resource management.

Both pressure and disabling institutional and social factors interact to steer household decisionmaking toward short-term goals, by forcing households to make tradeoffs between immediate requirements and long-term environmentally sustainable production. Poor households draw from the only capital available to them—natural resources. In the long-run, this can reinforce a vicious cycle between poverty and environmental degradation.

Environmental Constraints

Environmental constraints are a function of the naturally low biological potential of dryland areas (carrying capacity) and the high variability in climatic conditions that can lead to a high incidence of natural disasters. Drylands, by definition, have relatively low rainfall. In addition, total precipitation tends to be more erratic from year to year and more spatially variable than in humid regions. The high intensity of summer rains frequently leads to sudden, violent, damaging floods, particularly on degraded rangelands. Upland soils commonly are sandy or gravelly, with low productivity due to low nutrient content and water shortages (in contrast, lowland soils can be highly productive when irrigated and well-managed). Wind erosion is widespread and can be harmful to plants by causing sand blasting or burial. Associated
dust storms are also unpleasant and injurious to human and livestock health. Although typically less damaging to soils than water erosion, wind erosion has been associated with severe loss of topsoil, the most infamous case being the “Dust Bowl” of the 1930s in the U.S. midwest. Drinking water for humans and livestock is usually in short supply, except along the few permanent rivers, and groundwater in the more arid areas is frequently barely drinkable or undrinkable because of its salt content. Although human interventions can improve carrying capacities and mitigate the impacts of natural disasters, these constraints ultimately limit the productive potential of dryland areas and pose serious challenges to sustainable development in the drylands.

**Pressure Factors**

1. **Population growth** increases the demand for natural resources, resulting in higher intensity resource use. As population densities rise, subsistence farmers encroach on drought-prone marginal lands at the expense of traditional livestock areas. In addition, they may shorten fallow periods beyond what is required for soil recovery, thereby diminishing subsequent average yields per unit area of land. Overcropping and overstocking, combined with woodcutting to meet fuel needs, have denuded land of its natural vegetation and rendered it increasingly susceptible to wind and water erosion (Timberlake 1985). This situation is particularly manifest in the Sudano-Sahelian region of Africa, where drought conditions have been aggravated by overcropping and overgrazing to the extent that famine conditions have persisted for years and completely decimated livestock populations and vegetation cover. In China, a combination of dry farming, overgrazing, and fuelwood-gathering has resulted in accelerated wind erosion, with localized problems of drifting sand and formation of mobile dunes. Urbanization also plays a critical role, as growing urban centers expand and reduce the area available for agricultural production.

2. **Migration patterns.** Fast growing populations usually trigger migrations, especially of male workers who may leave to seek supplementary sources of income. This may reduce population pressure in rural areas; however, the migration of male workers may also lead to labor shortages and to a weakening of the traditional management regime (IFAD 1993).

3. **Natural disasters.** The high variability of climatic conditions and the extreme response by the landscape and the biota create behavior in the natural dynamics of these systems that humans consider to be natural disasters. However, the severity of the impact from natural disasters, such as drought, pest epidemics (for example, the recurrent epidemics of desert locust attacks in the dryland areas of North Africa and the Middle East), and flash floods are frequently exacerbated by inefficient resource management practices. The poor are usually the most vulnerable to natural disasters, and each episode lowers the resilience of their livelihood systems and of the natural resource base upon which they depend.

**Disabling Institutional and Social Factors**

Institutional and social factors determine the extent to which pressure factors are well managed. Appropriate institutional settings provide a necessary prerequisite for achieving resource conservation and sustainable management. Inappropriate institutional settings will inevitably have the opposite disabling effect. Key institutional considerations include the patterns of laws, policies and tenurial and organizational arrangements that ultimately shape both
societal and household decisionmaking and resource utilization patterns. These include the international and national policy environments which determine the incentive structure for sustainable land use, the institutional capacity for facilitating environmental management, and economic conditions that influence availability of private and public financial resources to invest in land management.

(1) Economic conditions can accentuate many of the processes contributing to unsustainable management of natural resources and to increased poverty in dryland areas. For example, the emergence of commodity markets has led to an increase in cultivation of cash crops in place of traditional crops. In some areas, the emergence of markets for cash crops have encouraged the planting of these crops on newly developed lands involving land clearing, leveling, and irrigation. In other areas, monoculture cash crops have become the norm, and contributed significantly to land degradation and loss of biodiversity. For example, in central Chile overexploitation of soils between 1967-1990 occurred when landowners sought to take advantage of a temporary boom in export prices (Aronson, Floret, Le Floch, Ovalle, and Potanier 1993).

The recent decline in world prices for agricultural commodities has had significant impacts on African farmers, who depend on one or a few commodities for a major share of their export income. To maintain incomes in times of falling prices, the area under export crops is expanded, often resulting in soil “mining” and excessive use of water and other inputs. Moreover, fluctuations in world prices (and export incomes) can translate into reduced productivity investments by farmers which, in turn, increases their vulnerability.

While reliance on a few export crops is an increasingly unattractive option in the face of falling commodity prices, diversification may be constrained by protectionist trade policies (such as subsidies that may lead to agriculture encroachment on rangeland) and by limitations on the transfer of technology. Very often, appropriate technology for the sustainable development of dryland regions is lacking (for example, environmental monitoring systems, improved crop varieties, and safe and effective pesticides). Furthermore, the costs of such technologies, coupled with transport and transaction costs, may be prohibitive.

The impacts of trade on resource management can work in both directions and are not entirely predictable. For example, if export crop prices are generally higher overall than domestic prices, trade opportunities may encourage investments in land, despite price variations. Additionally, export earnings generate the foreign exchange needed for many resource management technologies. A clear distinction needs to be made between inherent market failures and the policy and institutional failures described below which frequently distort markets.

(2) National social and economic policies. The combination of market demands and the need to balance various local and international political interests frequently leave governments with little room to maneuver; accordingly, national economic policy frameworks may not provide an enabling environment for sustainable land use in these fragile zones, and may even discourage sustainable agriculture and deepen poverty. For example, macroeconomic policies may preempt resource flows to low priority areas and fail to provide incentives for households
to undertake long-term investments. Distortionary pricing policies in the agricultural sector may favor planting certain crops to generate national food surpluses and ensure a consistent flow to urban consumers. Furthermore, social policies related to resettlement may unwittingly promote land degradation, such as the "villagization" program in northern and central Tanzania which reportedly led to the depletion of resources around settlements, while leaving distant lands uncultivated. Similarly, programs aimed at sedentarization of nomads may lead to widespread overgrazing around new settlements and water holes.

(3) Other institutional and social issues. The absence or the uncertainty of tenure can be a major deterrent to long-term sustainable resource use patterns. Moreover, inequitable distribution of land and transformation of communal lands into de facto open access resources through nationalization and ambiguities in usufruct rights of land, water, and trees can accentuate poverty and environmental degradation.

Jodha (1992) attributes the limited success of rural development interventions in dryland regions in India to ignoring the traditional role of common property resources (CPRs) in sustaining a natural resource base. Development policies have directly or indirectly contributed to the gradual erosion of the social arrangements that maintain CPRs. These social arrangements included village-based authority systems, consensual rules of contribution, and penalties for abusers. Their loss has led to the transformation of CPRs into open-access systems, inducing misuse of resources and land degradation.

The development of new technological systems in agriculture have also subjected dryland ecosystems to significant pressures. For example, the spread of mechanical traction has led to reduction in fallow cycles and intensified cropping practices in a manner that does not contribute to sustainable production. Likewise, the development of pumped water supplies has increased animal concentrations around water points. Rapid extension of mechanized cotton cultivation in Iran in the 1970s and unsustainable irrigation practices in the Indus plains of northwestern India and Pakistan have been directly linked to waterlogging, salinization, and other forms of land degradation.

In Sub-Saharan Africa, and in many other parts of the developing world, women are increasingly becoming responsible for decisions related to both farm and nonfarm activities as men continue to migrate to urban areas, and thus play a key role in resource management. Rural development programs which have failed to integrate women into the decisionmaking and the farm management system have not achieved their desired objectives. The marginalization of rural women can lead to serious misallocation of household resources and deterioration of the natural resource base. For example, in Zimbabwe hybrid maize was successfully introduced only after women's concerns about increased work load and control over extra income were addressed (Cleaver and Schreiber 1994).

Other institutional issues include lack of financial services, poor infrastructure, absence of savings structures, and poorly developed markets. Limited access to credit prevents investments in soil and water conservation measures, particularly if pay-back periods are relatively long. The absence of savings opportunities may encourage farmers to maintain their
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capital in the form of larger livestock herds, leading to imbalances in the use of rangeland resources. Lack of infrastructure inhibits the development of markets and supply of food relief. Poorly developed markets, poor integration of rural and urban markets, lack of adequate health services, low education levels, and the absence of strong and effective local institutions further constrain the sustainable development of dryland regions.

(4) Political and civil conflicts. Political and civil strife can exacerbate the negative effects of drought and land degradation in dryland regions by disrupting existing infrastructure and institutions, including supply routes and educational, health, research and extension services. Labor shortages can result if local people are called upon to participate in conflicts, leading to a breakdown in local management systems and institutions. Civil strife can lead to land abandonment and a return of native vegetation, but at a very high social cost.

(5) Poverty is widespread in the arid regions, particularly where crop production is attempted on marginal lands. It begins a self-perpetuating cycle of very low income, inability to make the improvements needed to increase yields and reduce risks, poor education, few health services, and other problems that keep the population impoverished. Systematic policy reform integrated with carefully targeted investment support is necessary to break this cycle.

Traditional Coping Strategies and their Implications

Traditionally, human populations in dryland regions have successfully used indigenous methods to optimize resource use and minimize risks to livelihoods. Pastoralists in Sub-Saharan Africa have adapted to the climatic stress in semi-arid regions by being mobile, by distributing livestock thinly to lighten grazing pressures, and by keeping a diverse herd of animals as an insurance against drought. When conditions are good, grazing is heavy; when range conditions are poor, pastoralists migrate to other areas, reduce livestock numbers, or seek employment in urban areas. For example, following the droughts of the early 1970s, farmers in the Lake Chad Basin changed from herds dominated by cattle and other large animals (mainly grazers) to herds of sheep and goats (mainly browsers).

Indigenous resource users also have their own ways of mitigating environmental risks in rainfed cropping areas. For example, farmers allow nomadic herders to graze their livestock on fallow lands in exchange for the fertilizing value of dung, and use long bush fallow periods to facilitate regeneration and protect the topsoil with vegetative cover. Diversified cropping is also practiced, with an emphasis on drought-resistant crops. Additionally, farmers respond to spatial variability in rainfall by farming several parcels of land that are fairly widely distributed.

Steinfeld, de Haan, and Blackburn (1996) argue that traditional management systems are characterized by continuous adjustments to rainfall variability, which operate under a continuous state of disequilibrium. This flexibility and mobility conserves land, especially in the more arid rangelands, as the low grazing pressure after a drought facilitates recuperation as it adjusts to the amount of feed available. Where land degradation occurs, this is mostly a result of misguided efforts to stabilize, through inappropriate land tenure and feed subsidy policies, a system which is by nature in continuous disequilibrium. For example, nationalization of rangelands replaced
natural habitats and ecosystems management in drylands

communal management systems with unregulated open-access systems. Policies to settle pastoralists, promote ranches, and regulate stocking rates reduced the flexibility of resource utilization, encouraging stock to graze in limited areas irrespective of local rainfall patterns. And drought emergency programs, which dished out subsidized concentrate feed, likely allowed too many animals to be maintained on stressed rangelands, preventing vegetation regeneration after the drought.

However, it is also true that the adjustments associated with decreased human and livestock populations as a consequence of drought represent tremendous human suffering which warrants intervention. Furthermore, traditional coping strategies, even if unhindered, are decreasingly effective in the face of expanding population pressures and land degradation.

Traditional household coping practices have evolved in response to changes in land quality, the frequency and severity of natural disasters, and socio-economic conditions. Migration to towns and to other rural areas in search of employment, increase in petty commodity production, use of inter-household transfers and loans, use of credit from merchants and money lenders, rationing of current food consumption, sale of possessions (for example, jewelry), sale of firewood and charcoal, consumption of food distributed through relief programs, sale of productive assets, and breakup of the household are some of the practices used to weather transitory disturbances to livelihoods.

A 1993 study by the International Fund for Agriculture Development (IFAD) indicates that household farming practices in drought prone areas may be changing from primarily risk minimization to loss management. Coping practices that were previously used only during periods of extreme stress are now more common. Some of these practices are environmentally damaging, such as the indiscriminate collection of fuelwood, and the pattern of repeated sales and re-acquisitions which diminishes incentives to invest in long-term productive capital. Alternatively, some coping strategies may reduce land-use pressures, such as the diversification of income sources through off-farm employment and non-agricultural production.

The IFAD study also found that the integration of households into the market system has decreased their reliance on mutual support systems (through the use of inter-household transfers and loans mentioned earlier). This, combined with a decline in the ability of farm households to respond to crises, has meant that a greater part of the responsibility of coping with drought has been shifted to government and nongovernment organizations through food relief programs.

In sum, livelihood systems in the drylands of developing countries are becoming increasingly vulnerable to drought, diminishing carrying capacity and the more complex socio-economic environment emerging in many dryland areas. Coping strategies formerly employed only during periods of stress have become a normal pattern of household behavior, but with decreasing effectiveness in the face of intensifying degradation pressures. Traditional management practices have considerable merit in their ability to respond to the interaction of human population growth, cropland encroachment, fuelwood demand, and livestock numbers; however, they must be adapted and incorporated into a broader strategy for natural resource conservation (Lusigi and Pratt 1995).
3 Management Lessons

Sustainable management of natural habitats and ecosystems in dryland regions requires a multifaceted approach. Improved technology can make a significant contribution by increasing livestock and crop yields when it is environmentally, socially, culturally, and economically acceptable. Yet improved technology is only one of the strategies needed to restore and conserve the natural resource base. Equally, or even more important, are enabling factors that create the conditions necessary to maintain biological diversity and ecosystems integrity. These factors are primarily associated with public policies and economic conditions.

Management strategies should aim to address two important resource-use processes:

1. Supply-based processes (for example, provision of better technology and services) to enhance the carrying capacity of dryland ecosystems; and
2. Demand-based incentives to encourage the use of environmentally-friendly technologies and family planning measures, along with sustainable resource use practices. Such practices would conserve the natural resource base within the constraints set by the naturally low carrying capacities of more arid dryland ecosystems.

Project experience indicates that the most effective strategies for promoting conservation of dryland resources include the following:

- Strengthening information and monitoring systems
- Improving dryland resource management by encouraging an “ecosystems” approach
- Developing integrated policies and programs to eradicate poverty, promote alternative livelihood systems, and manage risk, and
- Controlling population growth.

These are discussed in the following pages.

Strengthening the Knowledge Base

Global assessments of the status and rate of desertification conducted by the United Nations Environment Program in 1991 revealed the insufficiency of basic knowledge on land degradation and drought processes. These assessments indicated the need for integrated and coordinated information and systematic observation at national and local levels.

A coordinated system for information collection and planning provides local communities and national governments with more flexibility to respond to natural disasters. Early warning and monitoring systems such as UNEP Global Environmental Monitoring Systems (GEMS) and Sahara and Sahel Observatory (SSO) are important contributions. The International Drought Information Center at the University of Nebraska, United States, supports drought management efforts around the world. The Center publishes a drought newsletter,
conducts training courses on drought mitigation, and assists governments to establish national drought mitigation programs. It operates in cooperation with the World Meteorological Organization and the U.S. National Oceanic and Atmospheric Administration.

The Global Resources Information Database (GRID) is one of the first environment information programs established by the UNEP/GEMS in the early 1970s (Tolba and El-Kholy 1992). The GEMS program now spans 142 countries and includes monitoring in three main areas (atmosphere and climate, environmental pollutants, and renewable resources), as well as data exchange and assessment activities. The GRID program has benefited from the Geographical Information System (GIS), which allows data on a particular area to be stored in a computer program for rapid integration, inter-comparison, and manipulation (see box 1).

Many questions relevant to land degradation control remain unanswered. Among the technical uncertainties is how to determine the threshold level of land degradation,

**Box 1**

**Erosion and Land Degradation in Ethiopia**

Erosion and Land degradation have long been regarded as a major environmental problem in Ethiopia. However, there are few original assessments of the extent and rate of land degradation, and their results vary quite considerably. Most estimates of soil erosion rely on indirect measures such as those provided from use of the Universal Soil Loss Equation (USLE).

Past studies had estimated average annual soil losses as high as 130 tons/ha/yr from croplands and 35 tons/ha/yr from all land in the highlands, but did not make allowance for the redeposition of eroded soil within and between areas of productive land use. Inclusion of redeposition scenarios indicates that even under the least favorable redeposition scenario, only cropland and areas already considered to be unproductive are suffering net soil losses in excess of suggested rates of soil formation (24 and 48 tons/ha/year, respectively). Many other land areas appear to be receiving small net gains from redeposition. Immediate gross annual financial losses were estimated at US$2 million due to soil erosion and US$100 million due to nutrient losses.

These revised estimates do not in any way indicate that erosion and land degradation are trivial problems in Ethiopia. Rather, they indicate that the nature of problem is different and that different approaches are needed to meet sustainable land management objectives.

Soil conservation objectives can be met by use of a variety of both biological and structural soil conservation measures and there is considerable technical guidance available with regard to the choice of conservation measures for particular circumstances. The reduced rates of erosion suggested by the more recent studies indicate that the level of investment that society should direct to combating this type of land degradation is lower than previously considered desirable and, that proportionally, more resources should be directed to dealing with nutrient losses and other major problems such as education and health services, including family planning services. In particular, proposals for investment in the more expensive types of conservation measures such as terraces should be critically evaluated, and more emphasis should be placed on lower-cost, biological approaches to soil conservation and land husbandry.

The need for greater emphasis on low-cost biological approaches to soil conservation and local treeplanting initiatives to meet energy requirements underscores the necessity of creating an enabling environment that will maximize the opportunities for individual farmers and households to take private initiatives in land husbandry.

Sources: Hellden 1987; Bojo and Cassells, 1995
Management Lessons

beyond which further degradation becomes irreversible. Catastrophic theories of land degradation conclude that much, if not all, degradation is not reversible. In contrast, conservative theories contend that most degradation is reversible and that rehabilitation is almost always technically feasible. Research is badly needed to discover degradation control technologies that confer short-term and long-term benefits at a cost acceptable to farmers and pastoralists. Rigorous cost-benefit analyses are also needed to encourage economically rational priorities at the national level. Strong, demand-driven research organizations, combined with an effective extension service, are essential to obtain and transmit knowledge to help rural people solve their land management problems. Extension personnel must be well-trained and supported to be able to reach a wide range of land users, and must also possess proven, culturally-relevant technologies targeted at high-priority problems faced by agriculturists.

Improving Dryland Resource Management

The following section reviews key resource management issues associated with biodiversity, wildlife, water, soil and livestock. While each resource poses its own unique challenges, it must be managed in an integrated fashion that accounts for the interactions among different dryland resources and encompasses an “ecosystems approach” to resource management.

Conservation of Biological Diversity

Biodiversity in the drylands is the total variability of living organisms and the genes they contain from all ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems. Untold numbers of dryland species have become endangered or extinct in the past 100 years, and every dryland region on earth can be cited in lists of habitats containing rare and endangered species. Dryland degradation is an undisputed threat to biodiversity. Unfortunately, it is difficult to derive good measures that enable us to monitor such changes, and to link quantitatively the physical degradation caused by desertification to the subsequent biological degradation (IPED 1995).

Loss of species diversity is of global concern because biodiversity plays a critical role in maintaining the integrity of the arid, semi-arid, and dry sub-humid areas. The disappearance of plants and animals from the drylands limits development options and increases dryland inhabitants vulnerability to drought. Moreover, dryland species have played a critical role in agricultural development, particularly as the source of many of the world’s most important food crops, such as wheat, barley, sorghum, and millet.

Only limited research on biological diversity, species composition, characteristics and endemism has been conducted in the world’s drylands. Much of what has been done has been in developed countries such as Australia, the central Asian countries of the former Soviet Union, and the United States. Developing countries such as Kenya and Namibia have also made significant contributions to understanding dryland ecology. However, drylands remain a largely unknown domain. Identification of endangered species tends to be concentrated on popular game animals (white rhino, cheetah, elephant), rather than the hundreds of thousands of small animals, plants, birds, fish, and so on. Also overlooked are the microorganisms which constitute the fundamental building-stones in dryland production systems. Knowledge of dryland ecosystems and their genetic characteristics is an important tool in efforts to mitigate the effects of drought and combat desertification.
There are few places in drylands areas where there has been no human impact of some kind. Consequently, it can be difficult to determine the characteristics of the original, unaltered biological environment. The task becomes even more formidable as populations increase—cultivation expands into grasslands and forests; erosion strips away the soil cover; domestic and industrial wastes pollute soil, water, and air; grazing pressures increase; and exotic species of plants and animals are introduced.

The 1992 Global Biodiversity Strategy lists habitat loss and fragmentation due to expansion of farming into marginal areas as major causes of biodiversity loss (WRI, IUCN, and UNEP 1992). For the most part, croplands exhibit very little biological diversity except for microorganisms and insects in soils. Traditional mixed cropping frequently produces a rich combination of species, but agricultural ecosystems differ greatly from the original natural ecosystems. In modern mechanical farming, there is little biodiversity and any organisms present are largely influenced by fertilizers and pesticides. Simply taking land out of cultivation is seldom enough to reinstate the original mix of microorganisms, plants and animals.

Although croplands are not associated with species richness, dryland farmers have been the primary stewards of the genetic base for several globally important food crops (listed above). Based on their selections of seed for the next season, higher-yielding and more stress-tolerant crops plants have been developed over the millennia. Donor interventions to maintain agricultural biodiversity have typically focused on agricultural seed banks (ex situ storage); however, greater emphasis is now placed on preserving the genetic diversity in farmer’s fields (in situ conservation) (IPED 1995). (see box 2).

Riparian areas are generally the most biologically diverse habitats in terrestrial ecosystems, and take on a particularly critical role in arid climatic zones. These are the “islands” that sustain much of the biodiversity found in the drylands (IPED 1995). Grassland ecosystems used for grazing are also a focal point for maintaining and restoring biological diversity, as they contain much of the biodiversity found in prevailing arid land-uses. Although most grazing lands have been altered by human use, few have been so abused that land damage is irreversible. This is particularly true for wetter parts of the semiarid and dry subhumid zones, where protection from excessive grazing can do wonders for vegetative conditions. However, recovery in the drier areas may require decades, even if the vegetative damage is only moderate.

**Box 2**

**Farmer-Based Approaches to Conserving African Plant Genetic Resources, Ethiopia**

This GEF-financed project helps farmers maintain indigenous varieties of dryland corps such as teff, wheat and barley in the agro-ecosystem in which they evolved. In-situ conservation ensures that the complex interaction of genetically diverse cultivars with their environment, including pests, pathogens and droughts, is maintained so that their adaptations continue to evolve. The project provides training and assistance to communities to establish their own gene banks, and facilitates recording and documentation by the Ethiopian Plant Genetic Research Center, of the landraces and their adaptation. Through community-level capacity building it seeks to sustain and develop the use of dryland biodiversity and improve farm productivity.

Wildlife Conservation

Faced with national and international pressures from environmentalists during the last three decades, governments have pursued conservation policies which have frequently alienated local communities. For example, the establishment of national parks and reserves which may attract tourists, provide foreign exchange, and satisfy international commitments, have also frequently displaced rural communities from their traditional land. Moreover, anti-poaching laws turn the centuries-old practice of subsistence hunting into a crime. Many protected areas in the dryland regions of Africa have become small “islands” which are not large enough to accommodate the migratory patterns of the larger mammals. For example, in Senegal’s Niokolo Koba National Park, one of the largest habitat “islands” in Africa, the korrigum hartebeest, giraffe, and elephant are threatened with extinction because the park is not large enough to accommodate their movements. Restriction of movement also has implications for plant biodiversity outside of parks, as the wide ranging movements of animals provide an important contribution to floral biodiversity by spreading manure and scattering seeds carried by their hoofs. Moreover, experience indicates that these habitat “islands” tend to be expensive to maintain, and that parks may perform better if their enclosures are opened up and slowly integrated with the surrounding environment and the people.

Pressures on wildlife and natural habitats are especially acute in the fragile arid/semi-arid ecosystems of Africa, where continuing deterioration of the natural environment is eroding the continent’s unique wildlife heritage. However, in many areas currently facing conversion to agricultural use, development of wildlife resources may represent a more productive and sustainable form of land use, thereby reducing pressures to overexploit rangelands. The development of wildlife resources in drought-prone areas can supplement the incomes of subsistence farmers and decrease their vulnerability to drought, particularly where subsistence agriculture is the principal source of farm income and the establishment of irrigation facilities is not economically viable (Muir and Bojo 1994).

Recently, there has been a growing trend toward community-based wildlife management projects. Under these arrangements, investment plans are developed by local communities, which select specific interventions matching their own problems and needs and providing equitable benefit sharing. Projects are based on comprehensive and integrated resource management models. Projects are developed following an iterative manner and include the following components: (i) delineation of the area under management, (ii) setting of goals and objectives, (iii) multi-sectoral assessment of ecosystems based upon inter-sectoral functions, (iv) identification of tools and instruments that might be used to improve these functions, (v) testing of guidelines to select adequate tools, (vi) implementation and monitoring of plans, and (vii) periodic planning review. Community ownership and participation are emphasized at every step. The approach is multi-disciplinary and flexible enough to be applied to a diverse set of dryland problems.

Wildlife management in the Amboseli region of Kenya is based on greater integration between the Maasai populations and wildlife. Economic incentives are used to compensate landowners to set aside suitable land for wildlife grazing. In Botswana, livestock have encroached onto wildlife habitats due to the scarcity of pasture land and overgrazing. Several solutions have been implemented, including soil-conservation measures,
improved management of wildlife and national parks, provision of extension services to livestock breeders, and improved infrastructure, credit facilities, and pricing incentives/disincentives for the livestock sub-sector. Additionally, a portion of the income derived from tourism is channeled to local communities as an incentive to not overexploit the rangeland.

In 1983, the Tanzanian National Parks (TANAPA) and the African Wildlife Foundation developed a “Community Conservation Service” to encourage partnership between the national parks and neighboring communities. The Service selected the Loliondo Game Controlled Area adjacent to the Serengeti National Park for pilot studies. TANAPA focused on establishing an effective buffer zone to accommodate the regular movements of wildlife in the area within 10-15 km of the park boundary and to maintain the ecological integrity of the park. The needs of the Maasi were reconciled with conservation priorities in a number of ways. To date, traditional livestock grazing by the Maasai in the area has not presented a threat to wildlife movement, but the imminent development of commercial farming and ranching may. Maintaining this area as a buffer zone benefited the Maasai by allowing them to hold on to their land and maintain their lifestyle. Project design involved district and local political leaders and encouraged self-help activities within Maasai communities. Environment-related teaching materials were distributed to local schools, and mechanisms for sharing the proceeds of wildlife tourism and safari hunting between the district councils and the local communities were implemented. The CAMPFIRE project in Zimbabwe is based on the same idea. The project aims to reconcile wildlife management with expanding human populations (Box 3).

These new approaches to wildlife conservation in dryland areas have been based on the observation that people will actively participate in the sustainable management of wildlife resources if they participate in the economic benefits. In principle, these approaches are very similar to the “bioregional” approaches to management which emphasize cross-sectoral and, in some cases, transboundary cooperation, and participation by all affected stakeholders. Bioregions are areas rich in biodiversity where a management regime is established to coordinate land-use planning of both public and private landowners. Development options are designed to meet human needs without diminishing biodiversity (WRI 1995). Their success requires cooperation among various interests. With appropriate modification, such approaches could also be translated into action plans for sustainable resource use and biodiversity conservation in dryland regions.

Water Resources Management and Drought Preparedness

Many drought-prone countries have established central agencies responsible for water resource management. In most of them, harnessing scarce water resources forms a central component of their national plans and development schemes. Water scarcity can be alleviated in a few countries by tapping surface or groundwater supplies. However, if inappropriately managed, the latter can draw down water-table levels in non-renewable aquifers, as has occurred in Saudi Arabia. For most countries, the only available option is to make better use of finite supplies by increasing water use efficiency, and by shifting water consumption patterns from low-value crops to high-value crops and higher value domestic and industrial uses.

India’s Drought Prone Areas Program (DPAP) is designed to provide adequate buffers to farmers in the arid regions of Rajasthan to
The Community Areas Management Program for Indigenous Resources (CAMPFIRE) in Zimbabwe gives people an alternative to destructive land uses by making wildlife a valuable resource. Since its inception in 1989, CAMPFIRE has engaged more than a quarter of a million people in the practice of managing wildlife. It is targeted at Zimbabwe's Communal Areas, established in the early 1900s when European settlers claimed the most fertile land and forced much of the indigenous population into semi-arid and arid areas. Many of the communal lands are unsuitable for agriculture, but provide excellent wildlife habitat. CAMPFIRE is an attempt to use economic incentives to encourage the most appropriate management system for these fragile areas.

CAMPFIRE emerged with the recognition that as long as wildlife remained the property of the state, no one would invest in it as a resource, particularly not impoverished rural communities. Although private property owners have been able to claim ownership of wildlife on their land and benefit from its use since 1975, prior to CAMPFIRE, this right had not been extended to inhabitants of communal areas, which represent 42 percent of the country's population. CAMPFIRE begins when a rural community, through its elected representative body (Rural District Council), asks the Zimbabwe Wildlife Department to grant them the legal authority to manage its wildlife resources, and demonstrates its capacity to do so. The projects these communities devise to benefit from newly valuable wildlife resources vary from district to district. Most communities sell photographic or hunting concessions to tour operators—under rules and hunting quotas established in consultation with the wildlife department. Others choose to hunt or crop animal populations themselves, and many are looking at other resources, such as forest products. The revenues from these efforts generally go directly to households, which decide how to use the money, often opting for communal efforts such as grinding mills or other development projects.

CAMPFIRE, designed and managed entirely by Africans, has become a forum for a wide range of issues, including representation, economic participation, and the governance of communal areas. It is as concerned with the nature of rural communities and collective decision-making as with the technical challenges of sustainable use of wildlife. In many ways, it is an exercise in democracy. In fact, several members of Zimbabwe's parliament have come up through the ranks of CAMPFIRE. As a spin-off of its emphasis on community empowerment, it has enabled communities to enter into a debate on the management of protected areas, enhancing the likelihood of joint planning between communities and national parks.

The apparent strengths and achievements of the CAMPFIRE program include the following:
- Devolution of the benefits and costs of wildlife management has empowered communities;
- Allowing the consumptive and nonconsumptive use of wildlife has increased its value and improved its ability to compete with alternative land-uses;
- Institutions at the community level have evolved and indicate the capacity of communities, motivated by ownership of valuable natural resources, to organize themselves effectively; and
- The combination of improved tenure regimes and valuable resources has increased the incentives for better management—demonstrated by the development of common property institutions, improved land-use planning and management of the village commons, improved returns on forage use, and improved social infrastructure, welfare, household and food security.

Zimbabwe's Land Tenure Commission has recently drafted recommendations to further strengthen the tenure regime over natural resources. Current weaknesses apparent in the CAMPFIRE Program center around the incomplete devolution of property rights to the village level, the split in authority over resource access between legally recognized government officials and customary (traditional) leaders, and lack of mechanisms to address conflicts between villages. The overall tenurial framework remains incomplete because existing wildlife legislation supports districts, not villages; and only rights to wildlife have been devolved, not to the full bundle of natural resources upon which wildlife depends (grazing rights, water, etc.). In November 1995 the Commission strongly recommended that the Government recognize the traditional village, constituted under the village headman, as the basic unit of social organization in Communal Areas. Members of the traditional village should be given formal perpetual rights, jointly, to land and all resources in the village. A schedule of members would be maintained and the village would have rights to include or exclude new members. Thus communal land would no longer be State land, and villages could then sub-title residential and arable land, while retaining the commons as village property. As of June 1996, these recommendations were still under consideration.

This case study illustrates the complexity of designing tenure systems that establish strong and comprehensive rights over the use of natural resources for rural communities, and the need to reconcile conflicts between statutory (legal) and customary (traditional) authorities. It also demonstrates the tremendous impact that tenure reforms, albeit incomplete, can have on enhancing the value of wildlife resources and empowering local communities to manage them as a resource for sustainable development.

minimize losses when the monsoons fail. The project aims to maximize agricultural production in good rainfall years and sustain the population during bad rainfall years. Farmers are encouraged to take up subsidiary occupations like animal husbandry, poultry, sericulture and horticulture to reduce their dependence on agriculture. The DPAP has provided needy farmers with loans at low interest rates, along with a comprehensive package of facilities and services (including processing and marketing) to enable farmers to obtain remunerative prices for their produce. Infrastructure for dairying and sheep breeding has been developed to support cattle and sheep-rearing enterprises. Intensive cross-breeding programs have been established to expand wool production and improve its quality for carpets and apparel. Karakul sheep have been crossbred with hardy breeds like Malpura, Sonadi and Marwari to produce lamb pelts, introducing a more sustainable product which has raised the incomes of desert dwellers (UNEP 1983).

In drought-prone areas of Sub-Saharan Africa, water management strategies focus on providing buffers against drought. Since surface irrigation facilities have not been found to be cost-effective, other low-cost technologies are used to exploit groundwater supplies, such as counterbalanced pole-and-bucket shadoofs. In the Luaga region of Senegal, the establishment of forage plots and vegetable gardens irrigated with groundwater has drastically decreased the community’s vulnerability to drought and increased income levels (UN 1994). Mali has adopted similar schemes (see box 4). Emphasis on community participation and the provision of extension services to provide continued technical training to the beneficiaries have been important components of the process. One of the risks inherent in buffer strategies is that they will focus on alleviating the impacts of drought on human well-being at the expense of ecosystem health, thereby undermining the long-run sustainability of the natural resource base upon which dryland communities depend. For example, installation of water points for human and livestock use may convert traditional dry season grazing areas into year-round grazing.

### Box 4

**Droughts in Mali**

The Sahelian droughts of 1972-74 and 1984-85 killed 90 percent of the cattle and 70-80 percent of the sheep/goats, leaving many pastoralists in the area of Menaka Cercle destitute. Forests and grasslands suffered severely from the drought.

Successful management initiatives were implemented in the form of new water harvesting techniques and construction of cereal banks, in addition to a far reaching literacy campaign. Minifodder banks with manual water pumps were constructed. The abundant availability of groundwater on a long-term basis made possible the establishment of small irrigated potato home gardens. This coincided with increased expansion of the indigenous "Tokeur" technique for soil conservation; lands surrounding the cereal and potato gardens were converted into protected agroforestry home gardens, where cassava is grown with *Acacia albida* to regenerate and conserve soil.

The program’s success is attributed to the fact that the local people were actively involved in project formulation and site identification. Moreover, the community realized that the measures implemented directly addressed their needs and helped minimize the risks associated with drought. The sustainability of the resource conservation activities was assured by the presence in the area of a network of consultants and technicians provided by the initiative.

**Source:** United Nations 1994.
resulting in unsustainable land-use practices and degradation. Assessments of the impact of new water development on the whole ecosystem, and careful matching of water and grazing resources is critical. Use of temporary waterpoints (shallow ponds) may help to buffer the impacts of drought while mitigating the risk of degradation (Steinfeld and others 1996).

To sum up, in drought-prone Sub-Saharan Africa, where capital is limited and income levels are low, successful strategies for the development and management of water resources must rely on labor-intensive techniques that are easy to apply and can be easily adopted by the affected communities. On the other hand in China, and to some degree in India, governments have been prone to use engineering measures to solve the problem of water scarcity. A common element of both approaches is the provision of reliable buffers against drought combined with measures to increase productive capacities while maintaining ecosystem health (by conserving water, accessing groundwater, improving water storage, and diversifying livelihoods).

Soil Conservation

According to Cleaver and Schreiber (1994), soil degradation and erosion are largely insidious processes, not readily apparent to farmers until the effects are severe and irreversible under traditional means. They deplete the soil of nutrients, diminish its moisture retention capacity, and reduce the depth of the rooting zone for annual crops. Additionally, the destruction of soil structure diminishes rainwater seepage for groundwater recharge and increases localized surface runoff and the likelihood of flooding. These effects exacerbate the impact of drought.

Waterlogging and Salinity

Waterlogging and salinization are associated with poor management of irrigated croplands; namely, irrigation with brackish water and inadequate drainage leading to a rise in the level of the water table. It is thought that 50 percent of the irrigated land in the arid and semi-arid areas have been affected by varying degrees of salinization, with a subsequent reduction in crop yields and a restricted choice of crop varieties (Nahal 1995).

Waterlogging and salinization in Pakistan have been problematic since the introduction of perennial irrigation in the mid-nineteenth century. A major program to combat waterlogging and salinity was introduced in 1973, and involved sinking thousands of tube-wells for pumping groundwater, provision of surface and tile drainage, leaching of saline soils, and land leveling. As a result, water tables have been lowered in almost half the area originally affected, and productivity in the treated areas has increased by up to 250 percent. However, complex social and ambiguous tenurial relationships have hindered cooperation among local farmers. Uneconomically small holdings and involvement of farmers in off-farm activities have led to poor land preparation. Finally, inadequate extension services and low technical skills have resulted in water wastage and in extremely low average yields (UNEP 1987). This example underscores the importance of the role of appropriate institutional arrangements and stresses the need to provide continuing technical support so that conservation practices are adopted and implemented effectively by farmers.

Steps taken to remedy groundwater salinization in northwestern India include the exploitation of additional groundwater reserves, promulgation of sprinkler and drip irrigation, identification of cropping methods...
that minimize water use, and the selection of salt-tolerant crop varieties which can be irrigated with brackish water—all effective but relatively high-cost, technical solutions.

Dryland salinity in rainfed croplands has become a serious local problem in many parts of southern and western Australia as a result of broad-acre rises in water table levels due to the reduced evapotranspiration associated with forest clearance. Based on an analysis of alternative farming systems in a grazing area (Axe-Creek) and cropping area (Kamarooka), it was found that the problems of dryland salinity in both regions could be significantly reduced through minor changes in existing farming systems. These included modifications of fallow practices and the introduction of deeper rooted perennial grasses and legumes. A benefit-cost analysis indicated that reforestation and agroforestry can be profitable at low real discount rates; however, they require more significant changes in existing practices, entail larger capital investments, and therefore may be less easy to adopt and sustain (Dixon and others 1990).

In light of the above, solutions to waterlogging and salinization may sometimes warrant the implementation of both engineering and agronomic solutions, supported by adequate extension services. As illustrated by the Pakistan example, to increase the chances of success these solutions have to be tailored to meet the needs of the population through active participation from the beneficiaries. Low-cost solutions requiring low levels of capital investment are preferred by farmers. Higher rates of capital investment might require additional incentives to encourage farmers to adopt appropriate practices.

SOIL EROSION

Water and wind erosion affect tens of millions of hectares of rainfed cropland in the drylands. Water erosion is the principal land degradation threat to long-term soil productivity. Wind erosion is apparently a minor threat to potential on-site productivity, but a major cause of off-site damage (i.e. air pollution, soil deposition on roads and railroads). Water erosion, in the form of sheet, rill, and gully erosion, can cause a permanent loss of soil due to extremely slow rates of accumulation. In some soils, soil loss can be compensated for by adding organic matter and fertilizers. In very deep and uniform soils, such as those of the Loess Plateau in China, soils are hardly affected by erosion rates that would be considered very damaging anywhere else. However, efforts to restore productivity to shallow soils are unlikely to be successful.

Over the past few decades, many countries have taken actions to increase their capacities to support crop production by mitigating soil erosion. For example, Iran has restricted the extension of rainfed cropping and has made progress in halting further land degradation on farms. In northwest Pakistan, where water erosion has threatened water storage and irrigation works, special agencies have been established to deal with degradation of rainfed croplands. In northeast Thailand, special land reclamation programs are underway to establish perennial cropping.

In the Machakos district of Kenya, population growth caused marginal lands to be brought under cultivation to meet growing demand for food. Subsequent decline in soil fertility was compounded by low and irregular rainfall. In 1950, bench-type terraces were introduced to increase the infiltration of rainfall and reduce runoff (English 1994). By 1978, almost all the arable area in the settled part of the district had been terraced. A number of other factors were also responsible for improved productivity, including: (i) introduction of short-duration maize suitable for the area, thus increasing the likelihood of
a crop even in a relatively dry year; (ii) use of lighter plows with smaller teams of oxen, to make farming easier; (iii) use of animal traction to plow land before the rains arrived (normally, farmers had to wait for the first rain to soften soil before undertaking planting); and (iv) improved moisture infiltration, which allowed farmers to grow more trees and a number of cash crops. The Machakos experience illustrates the importance of innovation, characterized by a multitude of relatively small changes that provide an array of benefits, in facilitating the adoption of conservation measures (Tiffen and others 1994).

Simple stone contour bunds were successfully introduced in 1980 in an agroforestry project in the Yatanga Region of Burkina Faso, by training farmers in the basic principles of stone-bund construction and use of water tube levels. The project has helped ensure good yields in years of low and erratic rainfall. Successful adoption is attributed to the project’s simplicity, low initial costs and very small maintenance costs, immediate benefits (in terms of significantly increasing crop yields during the first year), and provision of support services (for example, farmers were provided with donkey carts or wheelbarrows where stones had to be transported over long distances) (Trolldalen 1990). A support system which is responsive to changing circumstances can help guarantee the sustainability of conservation practices in the long run.

Watershed degradation associated with soil erosion leads to failure of perennial flows, increase in flash-flooding, loss of water supplies for irrigation compounded by siltation of water storage structures, and deterioration in the amount and quality of water available for consumption, particularly in the dry sub-humid tropical countries. The World Bank’s India Watershed Plains project relies on the use of easily replicable strategies for improved land management practices in selected watersheds in Orissa, Uttar Pradesh and Rajasthan (Trolldalen 1990). Vegetative, soil and moisture conservation methods are emphasized, such as planting *Vetiver* grass, improving ground cover, and encouraging appropriate land uses that reflect peoples’ needs and land capabilities. Additionally, training and technical assistance to promote soil and moisture conservation technologies are provided to help the population implement conservation measures. Participatory planning is also stressed.

In the Weibei uplands of China, land-leveling was used as a main conservation measure to enhance the carrying capacity of the land (see box 5). A benefit-cost analysis showed that land-leveling, combined with irrigation, yielded the highest economic returns to farmers (Dixon and others 1989).

### Box 5

**Soil Conservation in Weibei, China**

In the Weibei upland in the eastern part of Guangzhong, Shaanxi Province, China, a combination of frequent droughts and high concentration of rainfall within short periods resulted in severe soil erosion. Crop yields were low and unstable, resulting in low income levels and poor living standards. To improve agricultural productivity in the area, a large-scale land-leveling program was carried out in 1984. Land-leveling prevented soil-erosion and provided the following benefits: (a) more efficient water use and lower irrigation costs for farmers, (b) easier cultivation requiring less human, animal, and machine power, (c) increased output per unit area and higher farm incomes, and (d) environmental and off-site benefits, leading to a more efficient and sustainable farming system.

In the Kitui district of Kenya, sporadic torrential rains caused severe soil erosion. Terracing has not only reduced soil erosion, but has also resulted in higher yields and crop diversification, reducing farmer’s risk. Although the initial labor investment for terracing is rather high, farmers are now terracing their fields at their own expense, prompted by the short-term tangible benefits demonstrated by early terracing efforts (Dixon and others 1989, ECA/FAO 1995).

**Loss of Soil Fertility**

The Zabre-Gomboussougou region in Burkina Faso provides an example of successful soil-conservation measures, based on the introduction of labor-intensive techniques that are easy to adapt and are appropriate to the socio-economic environment of the region. The soil’s nutrient level and its capacity to retain water had deteriorated to an extent where half the crops failed. To overcome the nutrient deficiency, a mixture of rock phosphate and compost, called “phospho-compost,” was added to farmers’ fields to overcome the soil phosphorus deficiency to increase soil organic matter content and to improve the water-retention capacity of the soil. Since this is a labor-intensive operation, the project organized 10,000 women in 300 village groups, and, through extension, taught them to produce compost using local materials (UN 1994).

**Improved Livestock Management on Rangelands**

Livestock can have both positive and negative effects on rangeland health. Grazing animals improve soil cover by dispersing seeds with their hoofs and through manure, while controlling shrub growth, breaking up soil crusts and removing biomass which otherwise might provide fuel for bush fires. These impacts stimulate grass tillering, improve seed germination, and may even enhance biodiversity, thus improving land vegetation. In mixed farming systems, livestock can be the critical element in maintaining soil fertility and facilitating erosion control. Similarly, mixed livestock-wildlife systems can increase rangeland productivity, and if well managed, the financial viability of sustainable land-use practices. Mixed livestock systems can thus provide an economic justification for maintaining a mosaic of land-use patterns, critical to the conservation of biological diversity (Steinfeld and others 1996).

On the other hand, heavy grazing causes soil compaction and erosion and decreases water infiltration and storage, soil fertility, and organic matter content. Overgrazing in hilly environments and the cultivation of marginal areas for feed production can accelerate erosion. Excessive concentration of livestock, resulting from the importation of large quantities of feed, can lead to saturated soils and contamination of water resources. Finally, increased intensification and industrialization, which requires uniform genotypes, has caused the extinction of some, and the genetic erosion of other, local livestock breeds. This is largely a result of development policies which favor exotic breeds and technologies that replace traditional drought animals. Although livestock have often been associated with deforestation and other forms of land degradation, it is not so much livestock per se which destroy the environment, but inappropriate management and external factors which cause livestock to shift from being a positive to a negative force in sustainable production (Steinfeld and others 1996).

Altering the incentive structure for overstocking and other unsustainable practices is an important step. Historically, the raison d’etre for keeping livestock was its use of resources for which there was no alternative, thus turning “wasteland” into food. The use of resources with no
opportunity cost explains why efficiency per animal has not been a major concern in many production systems. Failure to assign value to the stream of benefits of keeping ecosystems intact and maintaining productivity has distorted resource use decisions. Measures to correct the underpricing of dryland resources include levying grazing fees for communal areas; raising prices for inputs such as water, fossil fuel, and fertilizers; introducing cost recovery for water and animal health services; abolishing price supports for livestock products (and directly support farmers’ incomes if that is socially or economically desirable), and introducing equitable benefit sharing mechanisms for social and environmental goods (such as conservation of biological diversity). Removing incentives for land conversion is also important in preventing habitat degradation (Steinfeld and others 1996).

In degraded rangelands, the management challenge is to rehabilitate pasture ecosystems and maintain them in a productive state. China has had some success in rangeland management through reseeding, introduction of rotational grazing, and creation of enclosures to allow seasonal regeneration (see box 6). However, range improvement remains a high-risk endeavor because of low and erratic rainfall patterns.

Habitat Rehabilitation

Sand Dunes

Mobile sand dunes threaten croplands, rangelands, settlements and communications and thus lead to general environmental degradation. The greatest concern is on the margins of active dune fields where overcropping, overgrazing and fuelwood gathering have led to sand-mobilization.

Different techniques for sand dune

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**Box 6**

Rangeland Management in China

In the Shudiban and Jiujeng districts of Jingbian Country, Shaanxi, overgrazing placed a tremendous pressure on natural pasture lands. Recognizing this, in 1983 the Government mapped pasture lands and granted land-use rights to pastoralists, thereby providing incentives to manage pastures properly and to improve them. A system of rotational grazing was implemented whereby pastures were divided into three or four sections, to be grazed at predetermined times. Within one or two years, surveys indicated that vegetation cover had increased by as much as 4.5 times, flowering and fruiting plants were denser by 3.2 times, and sheep showed increases in body weight and higher wool yields.

A precise system of rotational grazing was developed on narrow pastures confined to lowlands. In the morning, sheep were brought to graze in a plot that had already been grazed twice. At noon they were transferred to a plot that had been grazed only once before. In the afternoon they were moved to an ungrazed plot. This process was continued until all the plots designated for grazing had been grazed three times. The quality of livestock improved under this system. At the same time, 40-50 percent of the pasture is kept free of grazing to allow its vegetation to recover.

The pastures in Otog and Uxin regions have been placed under an “enclose and care” program which prevents grazing during the growing season. In the autumn, enclosed fields are mowed when they are dense with such fine grasses as *Leymus secalinus* and *Calamagrostis pseudo-phragmites*. These fields offer stubble for grazing during winter and spring. Pastures not suitable for hay harvesting are rested during the growing season to permit the generation and accumulation of nutrients. The “enclose and care” program has produced excellent results even under relatively unfavorable conditions. Vegetative cover has increased and soils have shown considerable improvement in terms of physical condition and nutrient content. Thus, in addition to rehabilitating pasture ecosystems and maintaining them in equilibrium, enclosures contribute to a program of balanced feeding throughout the year.

Source: UNEP 1983.
stabilization have been developed and successfully applied in China, Iran, India, and the former USSR, including preliminary reshaping of dunes using mechanical means or floodwaters, arresting wind erosion with shelter-belts or palisades, stabilization of sand surfaces using bituminous mulches or barriers of dead vegetation, and planting of sand-fixing grasses, shrubs and trees.

"Grass kulums" are used in the Ujinxu sandy flats in China. These are enclosures of dunes, natural meadows, or plots between dunes where water and soil conditions are favorable. Enclosures are constructed of barbed wire, earthen bricks, or wicker fences to protect the land from overgrazing and other destructive activities. Pastures are protected against degradation by stabilizing dunes, planting and fencing off ranges, and constructing protective forest belts. In newly irrigated oases, land has been leveled, shelter belts planted, soil quality improved, and formerly barren lands cropped.

Along roads and highways that pass through deserts, engineering methods can be used to stabilize moving sands. Such measures have been implemented in Horqin, Yumen, the Tengger desert, and in the Shapotou district of China. These include building irrigation canals lined with rows of trees and building protective straw palisades in a checkerboard format, within which sand-fixing vegetation may be planted. However, these techniques are both expensive and labor-intensive.

**Afforestation**

Population growth and the subsequent pressure created on food and energy resources has been the main cause of deforestation and land degradation in the tropical regions. Fuelwood and charcoal are the main sources of domestic energy in many countries of Asia, Africa, and South America. Acute fuelwood shortages associated with rangeland degradation in the more densely populated and drier countries presents a daily burden, as people must travel increasingly farther to gather sufficient wood supplies. The off-farm use of dung and crop residues for fuel also contributes to soil deterioration and lower crop yields.

In a bid to remove some of these conflicts, China allocated lands to peasant families to establish forest-farms. Agroforestry programs were supported by awareness-raising activities among agricultural communities and the public at large, with emphasis on school children, teachers, community leaders, and village women. In India, nongovernmental organizations, such as the Society for Promotion of Wasteland Development in the Chipko movement, have played an important role.

The establishment of woodlots using community participation to afforest Kiambu district in Kenya provided a viable solution to the fuelwood crisis in the area (see box 7).

**Developing Integrated Programs and Policies**

Current livelihood systems in dryland areas are often inadequate and unsustainable, particularly in view of the effects of recurrent drought and increasing demographic pressure. Action is needed to rehabilitate and improve the sustainability of agropastoral systems to enhance the welfare of affected populations.

**Integrated Rural Development Programs**

An integrated approach to rural development is required to address multiple development objectives. Objectives may include, but are not limited to land reform, sustainable crop and livestock production, wildlife conservation, biosphere reserves, improved human welfare and population control.

Integrated rural development programs (IRDPs) pose serious implementation challenges in view of the limited institutional
Management Lessons

Box 7

Afforestation in Kiambu District, Kenya

Overgrazing and excessive fuelwood collection in the Kiambu district of Kenya have resulted in significant land degradation. The afforestation program worked with local communities by involving them in the decision-making process, and convincing them that land could be rehabilitated to meet their needs for food and fuel on a sustained basis. Members of the community were allotted pieces of land on which to grow their subsistence crops. In addition, each member was supplied with an assortment of seedlings to be planted in a mass woodlot.

Initially the community was unwilling to surrender land that was formerly available for grazing to tree planting. However, the awareness-raising component of the project brought about a positive change in attitudes. The established woodlots (primarily of *Acacia eucalyptus*) have produced both firewood and building materials needed by the community. Most importantly, the woodlot helped to increase productivity and yields because trees recycle nutrients through the ground litter. About 85 percent of the area is now under forest cover. The local communities have started to establish individual woodlots and tree nurseries in order to meet their wood needs.


Cross-Sectoral Policy Coordination

The use of biological resources, and the natural habitats that harbor these resources, is influenced by economy-wide government policies and programs. For example, continued urbanization and industrialization frequently reduce the area available for agriculture and place further pressure on farmers to intensify production and/or expand onto marginal lands. Strategies for implementing IRDPs have evolved in response to criticisms that many of the initial programs were too large and unwieldy. Early lessons from World Bank experience suggest that successful projects start small, then expand in scope only as constraints are removed. Learning by doing should be the basic premise of project operation. The principal factors affecting performance are: a) land policies, b) availability of appropriate technology, c) pricing and marketing policies, d) manpower resources and training, e) credit policies, and f) allocation of resources and local participation (Lele 1975). The success of an integrated rural development project in northern Pakistan (one of several Aga Khan projects) has been attributed to the integration of numerous development measures, including institution-building at the village level, placing responsibility on village organizations, paying special attention to innovation, monitoring the value of alternative practices, and adjusting the program in response to lessons learned as the project progressed (World Bank 1989).

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Box 8
Determinants of Effective Tenure Security

Tenure systems define who can (and who cannot) do what with a particular property in question, and under what circumstances. Further, tenure defines a relationship between people, not just between people and some physical property. That property may be farm land, grazing land, forest land, a river, a fishery, wildlife, or some other resource, including groundwater and minerals. Thus, tenure is not just about owning land, but encompasses a bundle of rights and responsibilities (Metcalf 1996, Lynch and Alcorn 1994).

The absence or the uncertainty of tenure has been identified as a major deterrent to long-term sustainable resource-use patterns. The nationalization of rural lands and ambiguities in usufruct rights of land, water, trees and wildlife has frequently turned communal lands into de facto open access resources, to the detriment of natural habitats and the well-being of rural communities.

Although much attention has focused on the problem of state ownership in reducing the incentives for resource management, Vincent and Binkley (1992) argue that the most critical issue for facilitating tenure security is specification of property rights, not state versus private ownership. Provided that land rights are exclusive, transferable, divisible, and enforceable, land users will face the same incentives as property owners to make appropriate investments to maintain the long-term productivity of land.

The Case of Forest Lands. For example, under a system in which forest land rights are granted by concession contracts, exclusivity is facilitated by clearly defined and acceptable criteria for renewal. This is generally what is meant by "security," and ensures that the concessionaire will reap any returns from harvesting at the economically optimal rate and investing in forest management. Transferability allows concession rights to be sold at any time. This reduces the risk of forestry investments because it allows investors to collect their return whenever they want. Divisibility allows "transfers to take place at their most efficient size. It allows concessions ultimately to have a size consistent with returns to scale in harvesting and management." Enforceability signifies that the Government can assure that the first three rights will be enforced. If these rights are enforced, the holder of a concession will face the correct implicit value of timber even if ownership remains vested in the State, because it will be able to benefit from investments in forest management during subsequent harvests (Vincent and Binkley 1992).

The Case of Rangelands. Usufruct rights in rangelands are particularly complex because wildlife resources are mobile and fugitive, and forage resources (graze, browse, water) are unequally distributed across the landscape. While usufruct rights may be clear within a village, they may be difficult to enforce between villages, particularly in times of resource pressure. Moreover, pastoralists frequently operate under dualistic tenure systems comprised of multiple tiers of customary and statutory resource regimes. These tenure regimes typically fail to account for the full bundle of resources on which wildlife depends. An effective tenure framework requires the cooperation of many parties, including individuals, communities, and government agencies at the village, ward, district and national levels—all of whom compete for control over natural resources. Associated transaction costs can be very high. This points to the need for land-use plans based on clear tenurial rights, which consolidate rules of access and provide a mechanism capable of allocating scarce resources productively, sustainably, and equitably. It also points to the need for efficient conflict resolution mechanisms in pastoral tenure systems (Metcalf 1996).

Policymakers must recognize that appropriate tenure systems need to account for cultural traditions, ecosystem conditions, and the specific security needs of resource users and owners—and thus need to be designed on a case-by-case basis, perhaps down to the village or user group levels. Considerable variance in form is expected across the landscape, and overlapping layers of multiple tenure systems may coexist in any one location. While all effective systems must be based on clear tenure rights, there may be different needs for flexibility within tenure systems.

It must also be recognized that tenure security is a necessary, but not a sufficient condition for sound resource management. Other enabling factors, such as access to credit and technological inputs may also be required. Additionally, a financial incentive for resource management requires that market prices for the output be sufficiently high to allow investments in resource management to out-compete alternative, less sustainable land uses and to render such investments economically viable. Last, pressure factors must not be so strong that they do not allow resources users to operate beyond a short time horizon.
Box 9  
Policy Coordination for Natural Resource Conservation 

Promoting Natural Resource Conservation in Structural Adjustment Policies. Experience has shown that Structural Adjustment Lending (SAL) operations have a mixed impact on the environment. Measures promoted by the SALs have often targeted economic growth in countries where environmental protection legislation and institutional capacity has been weak. Consequently, the impact of SALs on the environment, even though indirect, has in some cases been negative. For example, in Cameroon the SAL required a reduction of government employees. This led to a reduction in the number of park guards and weakened the country's capacity to carry out protection activities. In other cases, special conditionalities have been designed to enhance environmental management, such as fiscal policies to control timber exploitation or prevent unplanned extension into forest or rangeland areas. Still, inclusion of positive conditionalities remains the exception rather than mainstream experience.

In this regard, a useful strategy would be to ensure that sectoral environmental assessments are carried out for each structural adjustment proposal. These assessments could identify the major environmental issues facing key sectors in the country and evaluate how the adjustment proposal will affect these issues, or raise new ones. Where necessary, specific exemptions from staff cutbacks associated with environmental protection functions and/or specific institutional strengthening measures could be identified to ensure that apparent gains in economic efficiency are not obtained at the expense of a country's natural capital, including biodiversity (World Bank 1996).

Promoting Conservation in Natural Resource Policies. The economic analysis of natural resource conservation suggests that the following policies increase the incentives for managing natural resources on a sustainable basis (Pearce 1996):

- Invest in natural resources with economic value
- Ensure that this economic value is capturable—that institutions and markets exist which turn this economic value into a flow of real benefits
- Ensure that at least part of this flow of real benefits accrues to those whose livelihoods are dependent on the continued use of natural resources
- Avoid, wherever possible, conservation policies which ban or prohibit the utilization of natural products, since such bans take economic value away from wildlife and render it less capable of competing against alternative land uses, and
- Where such restrictions appear essential, ensure that compensation is paid to those who lose.

excessive pressure on the natural resource base (World Bank 1996).

Many important policy decisions affecting natural resource utilization are also taken at the level of individual sectors, such as agriculture, infrastructure, energy and transport. It is at this level, therefore, that policy making must incorporate resource management objectives if countries are to succeed in addressing their own conservation priorities, as well as respond to global concerns. Natural resource concerns need to be structured into country economic and sector work through the use of sectoral environmental assessments and other instruments. Such assessments should identify the main environmental concerns associated with the sector and design the policy and institutional responses and performance indicators needed to address these concerns. In key sectors such as agriculture and forestry, the development of locally relevant industry codes of practice may be appropriate ways of improving environmental performance and meeting other related sectoral objectives. Similarly, efforts need to be made to evaluate the impacts of Structural Adjustment Lending on natural habitats, and to promote conservation within natural resource policies (see to box 9) (World Bank 1996).
Box 10

Some Principles for Project and Program Design in Uncertain Environments

- Long time frames are needed for iterative planning with the involvement of resource users.
- Start small and build up, focusing on institutional capacity at the local level.
- Resist unrealistic disbursement targets.
- Projects are learning experiments; monitor performance through the use of appropriate criteria and indicators, and change course if necessary.
- Institutional and organizational flexibility are important to allow responses to unexpected events.
- Bureaucratic project structure and procedures will stifle innovation.
- A diversity of different organizations may be appropriate to tackle complex challenges found in pastoral areas: pastoral organizations, NGOs, producer's federations, and government agencies for example.


Environmental Planning

National environmental planning is needed to provide an analytical framework for integrating environmental considerations into the nation's economic and social development plans. One of the primary mechanisms for strengthening environmental planning has been the development of National Environmental Action Plans (NEAPs). Ideally, a NEAP is an in-country, demand-driven process based on participation of local communities. NEAPs define a time-bound program for action, including environmental policy, institutional, legal and economic reforms, and corrective measures and new investments to address distortions in the economy responsible for encouraging unsustainable resource-use practices. In countries which experience problems with desertification and drought, well prepared NEAPs are expected to mitigate the loss of soil fertility, deforestation, and other forms of land degradation.

Unfortunately, most of the NEAPs completed to date have not attached relative weights to the impact of various economic and noneconomic factors on land degradation. Availability of such a weighting system would facilitate choices among policy intervention mechanisms. For instance, if overgrazing contributes the most to land degradation compared to deforestation, then policy measures should target overgrazing. Lampietti and Subramanian (1995) indicated that physical and natural capital effects, irreversibility, equity, and monetary damage estimates are important factors for ranking land degradation. Similarly, the relative importance of various policy actions should be identified, based on the financial and institutional capacities of the country, compatibility with other programs, human health effects, ecological effects, potential for win-win outcomes, cost-effectiveness, and equity effects.

Environmental planning in drylands faces unique challenges posed by the high degree of uncertainty and risk that characterize drought-prone areas. This calls for adaptive planning processes and programs that can respond to changing conditions. Some principles for project and program design in uncertain environments are outlined in box 10.

Recently, strategies for pastoral development have evolved to better manage risk, by increasing the flexibility of response mechanisms. Table 2 highlights some differences between "old" and "new" development strategies, and are based on proceedings from a 1993 workshop on New Directions in African Range Management and Policy. The contrasts may tend to oversimplify; however, they serve to
### Table 2. Contrast between “old” and “new” strategies for pastoral development

<table>
<thead>
<tr>
<th>Issues</th>
<th>“Old”</th>
<th>“New”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Focus on commodity production (livestock development)</td>
<td>Focus on livelihoods (pastoral development)</td>
</tr>
<tr>
<td>Range Management</td>
<td>Open range improvement (legumes, fodder trees, rotations)</td>
<td>Focus on key resources: improvement, rehabilitation, creation</td>
</tr>
<tr>
<td></td>
<td>Paddocking and restrictive movement (fences)</td>
<td>Mobility and flexibility (no fences)</td>
</tr>
<tr>
<td>Planning</td>
<td>Blueprint development planning</td>
<td>Flexible, adaptive planning with local involvement and recognition of uncertainty</td>
</tr>
<tr>
<td>Drought Preparedness</td>
<td>“Normal” year development and drought relief separated</td>
<td>Drought “proofing” and safety net provision integrated</td>
</tr>
<tr>
<td></td>
<td>Focus on production issues in “normal” years</td>
<td>Focus on tracking (de/restocking, supplementary feeding, etc.)</td>
</tr>
<tr>
<td>Tenure</td>
<td>Fixed tenure regimes (privatization of exclusive communal systems)</td>
<td>Flexible tenure: complex mix of overlapping and integrated regimes</td>
</tr>
<tr>
<td></td>
<td>Conflict issues largely ignored</td>
<td>Focus on appropriate conflict resolution mechanisms</td>
</tr>
<tr>
<td>Institutions</td>
<td>Service delivery package through centralized extension services</td>
<td>Pastoral organizations for local management issues</td>
</tr>
<tr>
<td></td>
<td>Extension worked for technical delivery</td>
<td>Extension workers as “institutional organizers”</td>
</tr>
</tbody>
</table>


Stimulate reflection on the practical implications for development projects (Scoones 1993). Although they focus on African rangeland management issues, the essential concepts apply equally well to other dryland areas and resources.

### Reducing Population Growth

Reducing the rate of population growth is, in many but not all cases, essential to easing the pressure on land resources (see box 11). High population growth rates require higher agricultural productivity, which is achieved by intensifying crop and livestock production or by expanding the area of cropland or rangeland. Since most good land is already utilized for crops or livestock, expansion typically means exploitation of less productive lands, resulting in declining productivity on a per hectare basis. In comparison, intensification leads to higher yields and, probably in nearly all instances, to less land degradation, as seen in the Machakos District in Kenya (Tiffen and others 1994).

Governments are increasingly aware of the effects of rapid population growth and are implementing family planning programs to address the problem. Botswana, Kenya, and Zimbabwe have initiated population control programs that have doubled the contraception use rate from 16 percent to 33 percent. Community participation and popular support were identified as the key elements of success (Cleaver and Schreiber 1994).
**Box 11**

**Population Growth and Natural Resource Degradation**

Neither population size nor the population density of a country fully account for natural resource degradation or hunger. However, rapid population growth largely restricts a nation’s ability to adjust its policies and practices to accommodate changing conditions. The Mahaweli Regional Development Program in Sri Lanka illustrates the problems high population growth rates pose for development planners.

Begun in the 1970s as a 30-year program, this massive project was accelerated to a six-year program in 1977 in an attempt to keep abreast of the heavy social, economic, and political pressures generated by rapid population growth. However well intentioned, project acceleration made successful execution very difficult or impossible because of the sequential nature of major project activities. Even worse, speeding up the timetable led to emphasizing short-term results that did not protect important natural resources for the long-term. For example, no time was allotted to carefully design a road network. Consequently, a hastily-constructed network brought problems that could be rectified only at a high cost. Additionally, tree planting for fuelwood production was conducted too little and too late to meet the growing demand caused by population increases.

Ironically, even successful completion of the program in six years would not have kept pace with Sri Lanka’s rapid population growth.

*Source:* Kirchner and others 1985.

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Family planning, and efforts to reduce fertility through explicit population policies, should be integrated with policies to improve health, education and empowerment of women. Improving the legal, economic and social status of women helps to overcome constraints imposed by traditional roles. This is accomplished by providing greater educational and employment opportunities, removing of discriminatory laws, raising the marriage age, ensuring women’s rights to land, improving access to credit, and strengthening women’s organizations. Policies that contribute to reducing population growth levels must provide effective incentives for smaller families (and disincentives for larger families) at both household and community levels (such as cost-sharing for children’s health and education). A comprehensive population policy that targets improvements in human resource development is critical for long-term sustainable development.

In summary, dryland management strategies need to be flexible, adaptive, and responsive to feedback, particularly in view of the changing resource constraints associated with dynamic, non-equilibrium conditions in dryland regions (Harrison 1987). Special risk-management strategies are required, such as early-warning systems to alert land users and management to impending crises and help mitigate the effects of drought. Emergency fodder reserves and flexible transport systems to move stock and people out of drought-affected areas also help.

Management programs have to be sensitive to the cultural and social environments within which they are implemented (Leisinger 1995). Key stakeholders must perceive and enjoy the benefits of interventions to ensure their cooperation and increase the chances of success. This requires full community participation in development planning and management.

The processes that govern the sustainability of land use in dryland areas encompass a complex network of interactions between international, national and local levels. Consequently, the solutions have to be multifaceted, but focused on influencing household and community decisions.
regarding investments in productivity and conservation both on and off farm lands. Management objectives in dryland regions include sustainable agriculture development, poverty alleviation, and environmental conservation. Macro- and micro-economic policy instruments should aim to provide incentives to households to use dryland resources optimally. This implies management of pressure factors (population growth, migration, environmental constraints, and natural disasters) in combination with reform of disabling factors (national and international economic policies, institutional distortions, political conflicts, and poverty).
4 General Recommendations and Conclusions

Natural habitats and ecosystems management in dryland areas aims to maintain the integrity of the ecosystems while maximizing the benefits to communities who are dependent on the resources. Dryland interventions must therefore enhance the carrying capacity of dryland ecosystems (supply) and encourage the efficient use and conservation of existing resources (demand). Interventions should therefore emphasize an “ecosystems approach” that considers the interactions between resource users and the full range of natural resources that comprise ecosystems, and an “adaptive approach” that can readily respond to changing conditions in the face of uncertainty. The over-arching objectives are the conservation of the natural resource base and improved welfare of people directly dependent on dryland resources.

Although successful programs are mostly situation-specific, dryland management programs and projects are more likely to succeed if they are designed in a flexible yet integrated fashion and include the following elements:

**Strengthen information and monitoring systems:**
- Establish and/or strengthen environmental information systems at the local and national levels, and ensure cooperation between existing regional and global environmental information and monitoring systems;
- Strengthen national, state/provincial, and local environmental assessment; and
- Strengthen the capacity of national institutions to analyze environmental data and monitor environmental change, including systems to provide early warning of droughts.

**Improve dryland resource management through environmentally sustainable practice:**
- Promote protection and conservation of critical ecosystems and habitats through legislation and other means;
- Implement urgent, direct, preventive measures in drylands that are vulnerable or have been degraded by introducing (a) improved land-use policies, and (b) environmentally sound, socially acceptable, and economically feasible agricultural and pastoral technologies that facilitate soil and water resource conservation and habitat rehabilitation;
- Implement accelerated afforestation and reforestation programs using drought-resistant, fast-growing species combined with community-based agroforestry schemes;
- Promote improved land/water/crop-management systems to combat salinization in existing irrigated croplands and stabilize rainfed croplands;
- Intensify production on appropriate lands to reduce the need to cultivate marginal lands; and
Natural Habitats and Ecosystems Management in Drylands

Develop integrated programs and policies for dryland conservation and desertification control:

- Promote the development and use of alternative sources of energy to reduce pressure on the natural resource base.
- Promote rural credit and mobilize rural savings through the establishment of rural banking systems; and
- Develop infrastructure, as well as local production and marketing capacity.

Support indigenous technologies and local participation:

- Wherever possible, management interventions should adopt and improve indigenous techniques which have been traditionally used in dryland management. This includes the use of no-tillage and improved fallow and covercrops with indigenous legume crops. Where indigenous techniques need to be replaced, care should be taken to ensure that the new techniques are appropriate, are integrated effectively with the social and cultural backgrounds of the beneficiaries, and that extension services and training facilities are provided.
- Support direct local participation and reliance on locally available resources. Emphasis should be placed on involving the “right” groups of people.
- Recognize the importance of communities, not just households, in resource management.
- Schemes should be tailored to address the most pressing problems faced by the beneficiaries.

Develop programs to eradicate poverty and promote alternative livelihood systems:

- Decentralize land-resource management by delegating responsibility to rural organizations;
- Create or strengthen rural organizations in charge of village and pastoral land management;
- Institute legal, institutional and economic policy reforms ensuring cross-sectoral coordination to combat desertification.
- Develop national action plans to protect biodiversity, combat land degradation, focusing on the most important threats to biodiversity and causes of land degradation; and
- Develop integrated programs and policies for dryland conservation and desertification control.
- Strengthen land conservation authorities and community groups at the national and local level and encourage cooperation between stakeholders;
- Develop national action plans to protect biodiversity, combat land degradation, focusing on the most important threats to biodiversity and causes of land degradation; and
- Institute legal, institutional and economic policy reforms ensuring cross-sectoral coordination to combat desertification.
- Implement macroeconomic policies that provide incentives for sustainable resource management at the household level and remove distortions that act as disincentives to sustainable resource use at both the national and international levels.

Support for control of population growth rates:

- Provide family planning and health services as part of a well articulated national population policy plan; and
- Improve the legal, economic and social status of women by providing access to higher education, income earning opportunities, land, and credit.
References


References


APPENDIX: Characteristics of Drylands

Although precise definitions of dryland areas vary, general agreement exists on a number of characteristics. The principal defining characteristic is that mean precipitation is less than mean evapotranspiration for a significant part of the growing season. This means that rainfall is deficient for maximum plant production. The first globally accepted map of the drylands was prepared by Meigs (1953) for the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Meigs divided drylands into three aridity classes: extremely arid, arid, and semi-arid. Class boundaries were based on Thornthwaite's Moisture Index (Thornthwaite 1948) and on an analysis of natural vegetation distribution patterns. The author's personal judgment played a large role in locating aridity class boundaries.

UNESCO, with assistance from the Food and Agriculture Organization (FAO), the United Nations Environment Program (UNEP), and the World Meteorological Organization (WMO), published a revised drylands map for the 1977 United Nations Conference on Desertification (UNESCO 1979). This aridity map (figure 1) is widely accepted as the best drylands map in the world. It shows the distribution of four aridity classes: hyperarid, arid, semi-arid, and subhumid, based primarily on the ratio of precipitation (P) to potential evapotranspiration (PET), where PET is determined by the Penman method (Penman 1948). The hyperarid zone is what Meigs called the extremely arid zone. Boundaries between climatic zones reflect ecosystem distribution. The two UNESCO maps differ in many small areas but are generally similar.

Table A notes several characteristics of the four aridity zones depicted in the 1977 UNESCO map. The P/PET ratio that defines the nominal limits of each zone in Table A differs slightly from the ratios used in the

<table>
<thead>
<tr>
<th>Climatic zone</th>
<th>UNESCO</th>
<th>Atlas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperarid</td>
<td>9,181,000</td>
<td>9,781,000</td>
</tr>
<tr>
<td>Arid</td>
<td>19,260,000</td>
<td>15,692,000</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>17,706,000</td>
<td>23,053,000</td>
</tr>
<tr>
<td>Subhumid</td>
<td>14,873,000</td>
<td>12,947,000</td>
</tr>
<tr>
<td>Dry subhumid</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>61,020,000</td>
<td>61,473,000</td>
</tr>
</tbody>
</table>

drylands map included in the *World Atlas of Desertification*, published by UNEP for the 1992 United Nations Conference on Environment and Development. Although the Atlas map was also based on the P/PET ratio, the PET was calculated by the Thornthwaite method in place of the Penman method; the former requires much less data and is considered to be less accurate.

**Aridity Classes**

There are major differences between the boundaries of the four aridity classes in the UNESCO map and the Atlas map. Part of the difference arises from the UNESCO map having a subhumid zone in place of dry subhumid zone. Another difference arises because the Atlas map was constructed solely on the basis of the P/PET ratio calculated for several thousand weather stations, while the UNESCO maps reflect climate, soil, and vegetation patterns, as well as informed opinion.

Given the subjective nature of aridity zone boundaries (for example, P/PET < 0.03 or < 0.05 for the hyperarid zone), debate on the merits of one map over the other is fruitless. The 1977 UNESCO map is at a scale of 1/25,000,000 and copies are available from UNESCO in Paris. The Atlas map is at a scale of 1/115,000,000 and is not available as a separate map, only as a map in the *World Atlas of Desertification*. The difference in scale, alone, makes the UNESCO map preferable because of its greater detail. Additionally, a comprehensive calculation of the country-by-country area of land in each of the four aridity classes has been made from enlargements of the UNESCO map (Hopkins and Jones 1983). The UNESCO subhumid zone is actually a dry subhumid zone and is comparable to the Atlas dry subhumid zone.

Hyperarid regions are the true climatic deserts such as the Sahara, Atacama (Chile), Namib (Namibia), and Taklamakan (China). Vegetation is typically found only in dry stream beds, where groundwater is retained after rare floods. The arid climatic zone is nearly barren of vegetation in its drier areas, but the wetter part has a reasonably good cover of perennial and annual grasses as well as fairly tall shrubs. The semi-arid zone contains good grasslands, with some shrubs and trees. Rainfed cropping is frequently attempted in the drier part, but is successful only in above-average rainfall years. Perennial grasses are found nearly everywhere on undisturbed sites, and range in productivity from fair in the drier part of the zone to excellent in the wetter part. Most of the world's wheat lands, such as the Great Plains of the United States and Canada, are located in the semi-arid regions. Semi-arid lands are good grazing lands. However, cultivation in the dry part typically transforms good grassland into poor cropland. The dry subhumid zone is frequently a woodland of scattered trees and grasses in the dry portion and either a fairly dense woodland or an open forest in the wet fringes. The broader subhumid zone ranges from woodlands to fairly dense forests. All of the subhumid and dry subhumid lands are potentially good croplands.

Table A gives the area of land in each of the aridity zones, according to the UNESCO map and the *World Atlas of Desertification* drylands map. There is no significant difference between the two maps in the area of land in the hyperarid zone, despite the rather large difference in the P/PET criterion for that zone. Differences are large, however, in the sizes of the arid and semi-arid zones. As would be expected, the UNEP dry subhumid zone is smaller than the UNESCO subhumid zone, but only by about 15 percent. The total dryland areas, rather surprisingly, are virtually the same. It is surprising because

Table B lists some of the principal characteristics of the four aridity classes.
Table B. Characteristics of dryland climatic zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>P/PET Range</th>
<th>Vegetation</th>
<th>Land use</th>
<th>Annual precipitation range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperarid</td>
<td>&lt;0.03</td>
<td>Perennial vegetation largely confined to river beds; some growth of annual plants in favorable sites.</td>
<td>Grazing severely restricted or impossible. Irrigation practiced.</td>
<td>&lt;50 winter rainfall</td>
</tr>
<tr>
<td></td>
<td>&lt;0.05</td>
<td></td>
<td></td>
<td>&lt;100 summer rainfall</td>
</tr>
<tr>
<td>Arid</td>
<td>0.03-0.20</td>
<td>Woody shrubs, succulents, some perennial grasses, many annual grasses.</td>
<td>Grazing and irrigation practiced. No rainfed cropland.</td>
<td>50-200 winter rainfall</td>
</tr>
<tr>
<td></td>
<td>0.05-0.20</td>
<td></td>
<td></td>
<td>100-300 summer rainfall</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>0.20-0.50</td>
<td>Grasslands, shrubs, savannas.</td>
<td>Grazing, extensive rainfed cropland in wetter half of zone.</td>
<td>200-500 winter rainfall</td>
</tr>
<tr>
<td></td>
<td>0.20-0.50</td>
<td></td>
<td></td>
<td>300-600 summer rainfall</td>
</tr>
<tr>
<td>Subhumid</td>
<td>0.50-0.75</td>
<td>Grasslands, savannahs, woodlands.</td>
<td>Rainfed cropland, grazing.</td>
<td>500-1000 winter rainfall</td>
</tr>
<tr>
<td></td>
<td>n/a</td>
<td></td>
<td></td>
<td>600-1200 summer rainfall</td>
</tr>
<tr>
<td>Dry subhumid</td>
<td>n/a</td>
<td>Grasslands, savannahs, woodlands.</td>
<td>Rainfed cropland, grazing.</td>
<td>500-850 winter rainfall</td>
</tr>
<tr>
<td></td>
<td>0.50-0.65</td>
<td></td>
<td></td>
<td>600-1000 summer rainfall</td>
</tr>
</tbody>
</table>

*Mean annual precipitation divided by mean annual potential evapotranspiration.*

*UNESCO (1979).*

*UNEP (1992).*
the P/PET criteria for the drylands are quite different (0.75 vs. 0.65), the methods by which potential evapotranspiration was calculated are markedly different (Penman vs. Thornthwaite), and the base climate periods are different (variable years before 1977 vs. 1951-1980). Based on a total world land area of approximately 150,000,000 square kilometers, the drylands account for about 40 percent of the land area. Neither map shows the distribution of drylands in the Arctic and the dry valleys of the Antarctic.

**Soils**

Depending on the location and topography, dryland soils can be very diverse. In general, however, they possess many unique properties that distinguish them from soils in the humid regions (Dregne 1976). Commonly, they have a low level of organic matter and nitrogen, have a slightly acid to alkaline pH in the surface layer, contain varying amounts of calcium carbonate in the upper two meters, have only weak to moderate profile development, vary from shallow to deep above root-restricting layers, are coarse to medium textured in the uplands and fine textured in many river valleys and in the closed depressions that are unique to arid regions, exhibit low biological activity except after rains, and in the drier areas are frequently covered by a gravel layer called desert pavement. Most of these soils are deficient in phosphorus, subject to surface sealing (crust) and are prone to runoff and erosion. Soluble salts are common in the closed depressions and in upland soils derived from gypsum (such as the great Dasht-i-Kavir in Iran). Sandy soils are extensive in the semi-arid drylands, such as the Sahel, but massive sand dunes are largely confined to hyperarid regions. Gravely soils are more extensive than sandy soils in the uplands, globally.

There are many important exceptions to this generalized picture of dryland soils. A notable one is the strong acidity of sandy Sahel soils. Other exceptions include the extensive clay plains in central and eastern Sudan and the clayey soils in the Nile delta of Egypt and in the lower reaches of the Tigris and Euphrates river plain in Iraq. About 25 to 30 percent of irrigated soils are saline due to improper water management and the lack of effective drainage systems. Unfortunately, there is a long history of large irrigation projects constructed without any provisions for coping with the drainage problems that usually arise ten or so years after irrigation begins.

**Vegetation**

Vegetation in dryland regions varies according to climatic conditions and topography. The vegetation is extremely diverse and includes grasslands, shrublands, woodlands and forests. In the lower rainfall parts of the drylands, vegetation tends to be patchy, in response to frequently small topographic differences that shed or collect water. Spatial heterogeneity may also be due to factors other than climate, such as random fires and extreme droughts. Drought is a normal component of dryland climates, with the frequency and severity becoming greater as the climate becomes drier (at the global scale). Large fluctuations in rainfall lead to the apparent instability of ecosystems. However, plants and animals have evolved growth habits and physiological mechanisms to minimize aridity and drought effects, allowing ecosystems to bounce back from a severe drought and persist over the long term (Holling 1973). Arid ecosystems, in their natural state, have good resilience.

Large fluctuations in vegetation composition and productivity are common in most arid region ecosystems. While stability may be present in the sparse vegetative cover of the hyperarid and some arid zones, random events and subsequent recovery tend to keep the vegetation in a changing, non-equilibrium
APPENDIX: Characteristics of Drylands

state. Consequently, a steady level of productivity is seldom achieved, and most of the time rangeland ecosystems will be recovering from a random event, such as fire or drought. Productivity is low during droughts, but may be relatively high during wet periods. Despite these observations, the equilibrium view of ecosystems is frequently assumed by researchers when assessing the effect of management practices, leading to erroneous conclusions.

Although dryland ecosystems are resilient, aridity largely influences the time-frame necessary to increase biodiversity or productivity following a disturbance. Improving grasslands in the dry subhumid zone can be done much faster than improving rangelands in the arid zone, because rainfall is more reliable and less variable, as a rule, in the wetter zone.

It is important to recognize that droughts, by themselves, do not do irreversible damage to natural ecosystems. The greater damage is caused by adverse human interventions before and during droughts.

Biodiversity

Dryland ecosystems support a variety of plants and animals (for example, the Mediterranean climate of central Chile supports approximately 1,500 species in an area of less than 100,000 square kilometers). Dryland plants have evolved in ways that enable them to survive under drought conditions, and exhibit a wide range of morphological, physical, and chemical adaptations to their harsh environments. Some are drought-enduring (cacti) whereas others are drought-avoiding (annual grasses). Similarly, grazing animals adapt to climatic variability by migrating over hundreds of kilometers to take advantage of the seasonality and spatial variability in rainfall, and the resulting variation in forage production (Dixon and others 1989).

Although drylands have higher levels of within-species diversity than between-species variation (species richness), they contain significant endowments of plant and animal species, including microorganisms. MacMahon (1981) argues that biotic diversity in dryland areas is comparable to diversity in temperate forests, although many others argue that the richness of species declines with increased aridity, and that there is a positive correlation between species richness and rainfall. The humid tropics have both high endemism and biodiversity, while dryland areas have somewhat lower endemism and considerably less biodiversity (Mario Ramos, personal communication). Regardless, it is apparent that dryland areas are home to many species, some of which are quite abundant and unique. Sixty-four species out of 300 tropical medicinal plants, in one survey, and many of the most important food crops, originated in dryland areas. Moreover, wetlands within drylands (for example, the Hadeja-Nguru in Nigeria, the El Kala region in Algeria, and Cuatro Cienegas in Mexico) serve as indispensable nesting, resting, and breeding grounds for important migratory species.