GRASSLAND ECOSYSTEMS

The goods and services provided by the world's grasslands have received far less attention than those supplied by, for example, tropical forests and coral reefs, although grasslands are arguably more important to a larger percentage of people. Grasslands are home to 938 million people–about 17 percent of the world's population (White et al. [PAGE] 2000). They are found throughout the world, in humid as well as arid zones, but grasslands are particularly important features of the world's drylands. Approximately half of the people living in grassland regions live in the world's arid, semiarid, and dry subhumid zones (White et al. [PAGE] 2000). Scant rains make these drylands particularly susceptible to damage from human management and slower to recover from degradation such as overgrazing or improper cultivation practices.

Grassland ecosystems have historically been crucial to the human food supply. The ancestors of nearly all the major cereal crops originally developed in grasslands, including wheat, rice, rye, barley, sorghum, and millet. Agroecosystems have replaced many grasslands, but grasslands still provide genetic resources for improving food crops and are a potential source of pharmaceuticals and industrial products.

Grasslands are important habitats for many species, including breeding, migratory, and wintering birds, and support many wild and domestic grazing animals. Grassland vegetation and soils also store a considerable quantity of carbon. Other grassland ecosystem goods and services include meat and milk; wool and leather products; energy from fuelwood and wind generated from windfarms; cultural and recreational services such as tourism, hunting, and aesthetic and spiritual gratification; and water regulation and purification. PAGE researchers examined four of these goods and services: food production, biodiversity maintenance, carbon storage, and tourism (Box 2.29 Taking Stock of Grassland Ecosystems).

Extent and Modification

PAGE researchers defined *grassland ecosystems* as "areas dominated by grassy vegetation and maintained by fire, grazing, and drought or freezing temperatures." Using this broad definition, grasslands encompass nonwoody grasslands, savannas, woodlands, shrublands, and tundra. Grassland ecosystems are found on every continent. Among the most extensive are the savannas

(continues on p. 122)

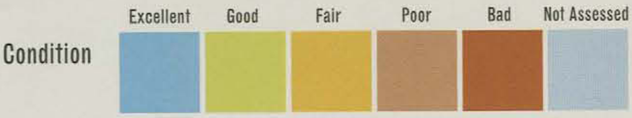
Box 2.29 Taking Stock of Grassland Ecosystems

Highlights

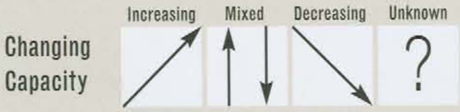
- Grasslands, which cover 40 percent of the Earth's surface, are home to almost a billion people, half of them living on susceptible drylands.
- Agriculture and urbanization are transforming grasslands. For some North American prairies, conversion is already nearly 100 percent. Road-building and human-induced fires also are changing the extent, composition, and structure of grasslands.
- All of the major foodgrains—corn, wheat, oats, rice, barley, millet, rye, and sorghum—originate in grasslands. Wild strains of grasses can provide genetic material to improve food crops and to help keep cultivated varieties resistant to disease.
- Grasslands attract tourists willing to travel long distances and pay safari fees to hunt and view grassland fauna. Grasslands boast some of the world's greatest natural phenomena: major migratory treks of large herds of wildebeest in Africa, caribou in North America, and Tibetan antelope in Asia.
- As habitat for biologically important flora and fauna, grasslands make up 19 percent of the Centers of Plant Diversity, 11 percent of Endemic Bird Areas, and 29 percent of ecoregions considered outstanding for biological distinctiveness.

Key

Condition assesses the current output and quality of the ecosystem good or service compared with output and quality of 20–30 years ago.



Changing Capacity assesses the underlying biological ability of the ecosystem to continue to provide the good or service.



Scores are expert judgments about each ecosystem good or service over time, without regard to changes in other ecosystems. Scores estimate the predominant global condition or capacity by balancing the relative strength and reliability of the various indicators. When regional findings diverge, in the absence of global data weight is given to better-quality data, larger geographic coverage, and longer time series. Pronounced differences in global trends are scored as "mixed" if a net value cannot be determined. Serious inadequacy of current data is scored as "unknown."

Conditions and Changing Capacity

FOOD PRODUCTION

Many grasslands today support high livestock densities and substantial meat production, but soil degradation is a mounting problem. Soil data show that 20 percent of the world's susceptible drylands, where many grasslands are located, are degraded. Overall, the ability of grasslands to support livestock production over the long term appears to be declining. Areas of greatest concern are in Africa, where livestock densities are high, and some countries already show decreases in meat production.

BIODIVERSITY

Regional data for North America document marked declines in grassland bird species and classify 10–20 percent of grassland plant species in some areas as nonnative. In other areas, such as the Serengeti in Africa, In other areas, such as the Serengeti in Africa, population levels of large grassland herbivores have not changed significantly n the past 2 decades.

CARBON STORAGE

Grasslands store about one-third of the global stock of carbon in terrestrial ecosystems. That amount is less than the carbon stored in forests, even though grasslands occupy twice as much area. Unlike forests, where vegetation is the primary source of carbon storage, most of the grassland carbon stocks are in the soil. Thus, the future capacity of grasslands to store carbon may decline if soils are degraded by erosion, pollution, overgrazing, or static rather than mobile grazing.

RECREATION

People worldwide rely on grasslands for hiking, hunting, fishing, and religious or cultural activities. The economic value of recreation and tourism can be high in some grasslands, especially from safari tours and hunting. Some 667 protected areas worldwide include at least 50 percent grasslands. Nonetheless, as they are modified by agriculture, unbanization, and human-induced fires, grasslands are likely to lose some capacity to sustain recreation services.

Data Quality

FOOD PRODUCTION

Soil degradation can be determined globally, but assessment often relies on expert opinion, and the scale of the data is too coarse to apply to national policies. Data on livestock density in grasslands include global and some regional coverage, but only for domestic animals. We still lack corresponding studies of vegetation, soil condition, management practices, and long-term resilience. Data on meat production are available globally, but meat produced from livestock raised in feedlots cannot be separated from meat produced from range-fed livestock.

BIODIVERSITY

Long-term trends in grassland bird populations can be assessed from comprehensive regional data for the United States and Canada. Some long-term regional data within Africa show steady levels of major herbivore populations, but geographic coverage is limited. Other regional, national, and local data for grassland species lack long-term trends. Regional and local coverage of invasive species are more descriptive than quantitative.

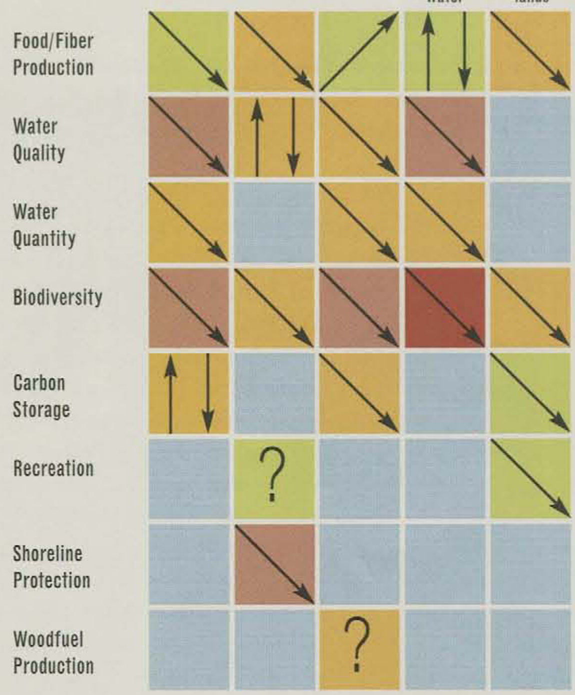
CARBON STORAGE

Methods for estimating the size of carbon stores in biomass and soils continue to evolve. This study relied on previous global estimates for above- and below-ground live vegetation, updated to fit the current land cover map by the International Geosphere-Biosphere Programme, with the addition of soil carbon storage estimates. Models are needed to incorporate carbon storage modifications based on different management practices.

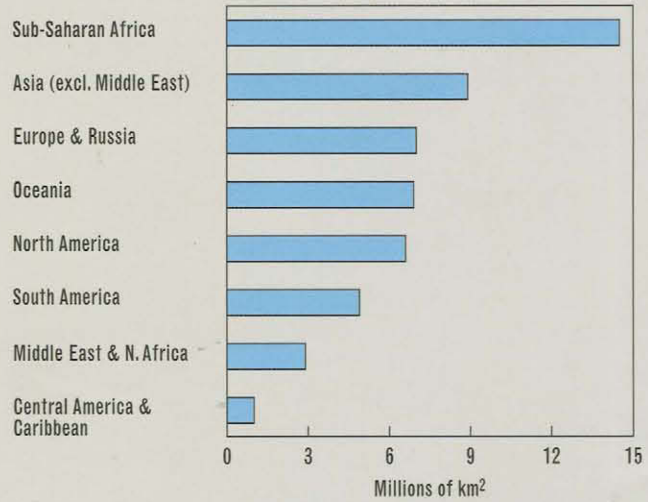
RECREATION

Regional information evaluates the exploitation of grassland wildlife but summaries are based primarily on expert opinion. Global country-level expenditures on international tourism provide estimates for all types of tourism but cannot be related specifically to grasslands. Regional data for tourism and safari hunting are good for some areas but rarely report long-term trends.

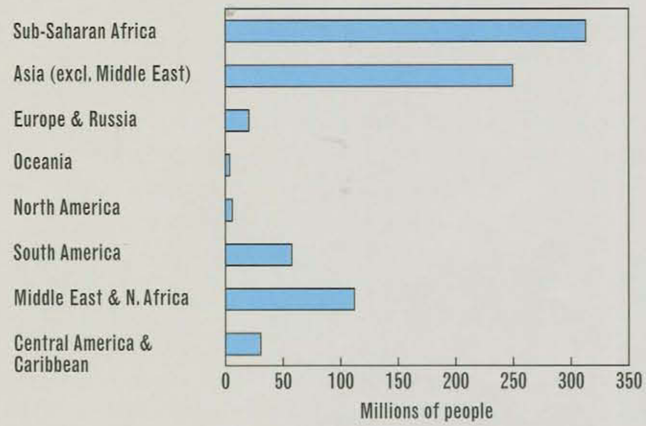
Scorecard



Area of Grassland Ecosystems



Population of Grassland Ecosystems



of Africa, the steppes of Central Asia, the cerrado and campo of South America, the prairies of North America, and the grasslands of Australia.

Extent

Estimates of the extent of the world's grassland ecosystems range from approximately 41 million km^2 to 56 million km^2, covering 31–43 percent of Earth's surface (Whittaker and Likens 1975:306, Table 15-1; Atjay et al. 1979:132–133; Olson et al. 1983:20–21). The differences among estimates are due, in part, to different definitions of grasslands; for instance, different researchers include more (or less) tundra or shrubland.

Using land-cover maps generated from recent satellite data, PAGE researchers produced a new map of the extent of the world's grasslands (Box 2.30 Global Extent of Grasslands). Some of the grasslands in this map are actually mosaics of grasslands and other land uses such as agriculture but are considered to be grasslands when those "other" land uses cover 40 percent or less of the area. Mapped this way, grassland ecosystems cover 52.5 million km^2–about 41 percent of the world's land area (excluding Antarctica and Greenland)–much more than forests or agroecosystems. Indeed, on a national basis, grasslands are one of the most common and extensive types of land cover. In 40 countries, grasslands cover more than 50 percent of the land area, and in 20 of these countries–most of them in Africa–grasslands make up more than 70 percent of the land area.

Grasslands are a significant ecosystem in many of the world's important watersheds as well. For example, grasslands comprise more than 50 percent of the land area in these watersheds: the Yellow River in China; the Nile, Zambezi, Orange, and Niger Rivers in Africa; the Rio Colorado in South America; and the Colorado and Rio Grande in North America (White et al. [PAGE] 2000). The extent of grasslands in these watersheds underscores the importance of managing grasslands so that they retain their watershed functions of absorbing rainfall to recharge aquifers, stabilizing soils, and moderating runoff. These essential watershed services are an often underappreciated aspect of grasslands.

Modifications

Like forests, the world's grasslands have lost much of their original extent through human actions–mostly conversion to agriculture. Scientists have no easy way to determine the extent of global grasslands prior to human disturbance, and thus no easy way to determine the exact amount of grasslands lost over time. However, PAGE researchers obtained a good rough estimate of historical loss by comparing current grasslands extent to "potential" grassland areas–those areas where grasslands would be expected to exist today (based on soil, elevation, and climate conditions) if humans had not intervened.

Using this approach, PAGE researchers examined in depth five regions for which the potential vegetation would likely be 100 percent grassland in the absence of humans disturbance. Among these regions, the Tallgrass Prairie in North America shows the greatest change. Croplands cover 71 percent of this region and urban areas cover 19 percent. In contrast, the grassland regions in Asia, Africa, and Australia each retain at least 60 percent of their area in grasslands with less than 20 percent in cropland and less than 2 percent in urban or built-up areas.

FIRE

Fire is a natural occurrence in most grassland ecosystems and has been one of the primary tools humans have used to manage grasslands. Fire prevents bushes from encroaching, removes dry vegetation, and recycles nutrients. Without fire the tree density in many of the world's grasslands would increase, eventually converting them to forests. In addition, fire helps hunters stalk grassland species and helps farmers control pests (Menaut et al. 1991:134).

Natural fires–typically caused by lightening–are thought to occur about every 1–3 years in humid areas (Frost 1985:232) and every 1–20 years in dry areas (Walker 1985:85). But today, the number of natural fires is insignificant compared to the number of fires started by humans (Levine et al. 1999:1). Humans have set fires in the savannas for at least 1.5–2 million years and continue to use fire as a low-cost and effective means to manage grasslands (Andreae 1991:4). Today, for example, in many African countries people use burning to maintain good forage conditions for grazing herds of livestock and to clear away dead debris (Box 2.31 Grassland Fires). Some 500 Mha of tropical and subtropical savannas, woodlands, and open forests now burn each year (Goldammer 1995, cited in Levine et al. 1999:4).

Although fire can benefit grasslands, it can be harmful too–particularly when fires become much more frequent than is natural. If too frequent, fire can remove plant cover and increase soil erosion (Ehrlich et al. 1997:201). Fires also release atmospheric pollutants. Because much of the biomass that is burned each year is from savannas, and because two-thirds of Earth's savannas are in Africa, UNEP reports that Africa is now recognized as the "burn center" of the planet (Levine et al. 1999:2). Burning of savannas is responsible for more than 40 percent of the carbon emissions from global biomass burning each year (Andreae et al. 1991:5).

FRAGMENTATION

Globally, grasslands have been heavily modified by human activities. Few large unaltered expanses remain (Box 2.32 Fragmentation of American Grasslands). Even many smaller grassland areas are extensively fragmented (Risser 1996:265). Fragmentation can affect the condition of grasslands in many ways, increasing fire frequency, degrading habitat, and damaging the capacity of the grassland to maintain biological diversity. Agriculture, urbanization, and road building are the biggest sources of grassland fragmentation, but livestock

Box 2.30 Global Extent of Grasslands

Grasslands are found on every continent and cover approximately 41 percent of Earth's land area (excluding Greenland and Antarctica). To gauge the impact of human activity on the extent of grasslands, PAGE researchers looked at five regions that could be expected to be entirely grasslands, based on current climate and geographic conditions. Of these the Tallgrass Prairie in North America shows the greatest change, with grasslands now accounting for only 9.4 percent of the total area. Only 21 percent of grasslands remains in South America. By contrast, more than 50 percent of the regions selected in Asia, Africa, and Australia remain as grasslands.

Estimated Grassland, Remaining and Converted (percent)

Continent and Region	Remaining in Grasslands	Converted to Croplands	Converted to Urban Areas	Total Converted
N. America Tallgrass Prairie in the United States	9.4	71.2	18.7	89.9
S. America Cerrado Woodland and Savanna in Brazil, Paraguay, and Bolivia	21.0	71.0	5.0	76.0
Asia Daurian Stepppe in Mongolia, Russia, and China	71.7	19.9	1.5	21.4
Africa Central and eastern Mopane and Miombo Woodlands in Tanzania, Rwanda, Burundi, Dem. Rep. Congo, Zambia, Botswana, Zimbabwe, and Mozambique	73.3	19.1	0.4	19.5
Oceania Southwest Australian shrublands and woodlands	56.7	37.2	1.8	39.0

The Global Extent of Grasslands

Sources: White et al. [PAGE] 2000. Map is based on the Global Land Cover Characteristics Database Version 1.2 (Loveland et al. 2000). The map shows all lands where grassland made up at least 60 percent of each 1 km^2 satellite mapping unit. Tundra areas are estimated using the Olson Global Ecosystem classification; all other areas are estimtaed from the International Geosphere-Biosphere Programme classification. Table is based on data from WWF and this map.

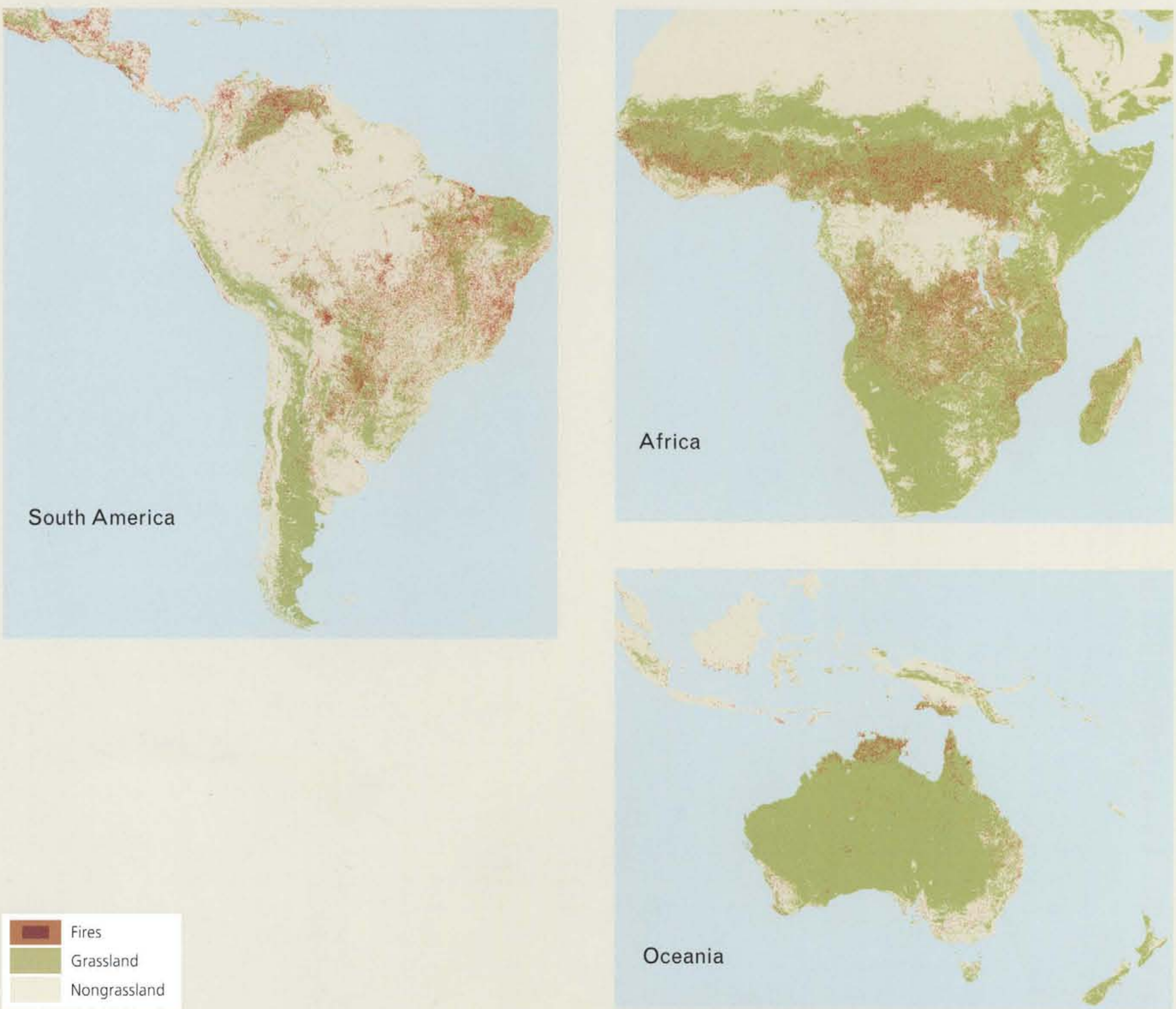
Box 2.31 Grassland Fires

Fire plays a vital role in determining the character and extent of the world's grasslands. Fires clear dry vegetation, prevent bush encroachment, and recycle nutrients. Without them, much of the world's grasslands would eventually become forested.

Today, the number of natural fires, typically caused by lightning, is insignificant compared with the number set by humans, who have used fire for millennia to hunt, clear land for cultivation and grazing, remove dead debris, and kill pests. Deliberate burning of grasslands is widely practiced in many African countries, with 25–50 percent of total land surface in the arid Sudan Zone and 60–80 percent in the humid Guinea Zone burned annually (Menaut et al. 1991:137).

Fires can be beneficial for grassland ecosystems, but if they become too frequent, they can remove vegetation cover and increase soil erosion (Ehrlich et al. 1997:201). In addition, fires are a significant source of atmospheric pollutants and carbon emissions, with savanna fires, mostly in Africa, accounting for a large proportion of the carbon released into the atmosphere as a result of biomass burning.

Fires Detected by Remote Sensing in Africa, South America, and Oceania, 1993



Source: White et al. [PAGE] 2000. Map is based on Arino and Melinotte (1998) and Global Land Cover Characteristics Database Version 1.2 (Loveland et al. 2000).

fencing and the spread of woody vegetation into grasslands also cause significant fragmentation and harm to native species.

One way to evaluate fragmentation is visually–using habitat maps and expert opinion to gauge the size of habitat blocks and the degree of fragmentation in an area. Using this approach, an analysis of 90 grassland regions in North and Latin America showed that the most heavily fragmented grasslands were in temperate and subtropical zones of North America, where there has been extensive agricultural development (Dinerstein et al. 1995:78–83; Ricketts et al. 1997:33, 147–150).

Another way to assess the pressure of fragmentation is to measure the extent to which road networks have contributed to the breakup of larger blocks of grasslands. PAGE researchers used this approach to measure fragmentation in two pilot regions: Botswana and the Great Plains in the United States. In Botswana, if the impact of roads is not considered, 98 percent of the grassland area is found in patches of at least 10,000 km^2. What little fragmentation researchers did observe is caused mainly by agricultural development or natural factors like rivers. When fragmentation by the road network is included, fragmentation increases somewhat, but 58 percent of the area still remains in 10,000 km^2 patches. In contrast, in the Great Plains of the United States, road fragmentation is pervasive. If the effect of roads is ignored, 90 percent of the grassland area is in patches of 10,000 km^2 or greater. But when roads are factored in, 70 percent of the area is in patches less than 1,000 km^2 and none larger than 10,000 km^2.

LIVESTOCK GRAZING

Grasslands and grazing animals have coexisted for millions of years. Large migratory herbivores–like the bison of North America, the wildebeest and zebra of Africa, and the Tibetan antelope of Asia–are integral to the functioning of grassland ecosystems. Through grazing, these animals stimulate regrowth of grasses and remove older, less productive plant tissue. Thinning of older plant tissues allows increased light to reach younger tissues, which promotes growth, increased soil moisture, and improved water-use efficiency of grass plants (Frank et al. 1998:518).

Grazing by domestic livestock can replicate many of these beneficial effects, but the herding and grazing regimes used to manage livestock can also harm grasslands by concentrating their impacts. Given the advantages of veterinary care, predator control, and water and feed supplements, livestock are often present in greater numbers than wild herbivores and can put higher demands on the ecosystem. In addition, herds of domestic cattle, sheep, and goats do not replicate the grazing patterns of herds of wild grazers. Use of water pumps and barbed wire fences has lead to more sedentary and often more intense use of grasslands by domestic animals (Frank et al. 1998:519, citing McNaughten 1993). Grazing animals in high densities can destroy vegetation, change the balance of plant species, reduce biodiversity, compact soil and accelerate soil erosion, and impede water retention, depending on the number and breed of livestock and their grazing pattern (Evans 1998:263).

Assessing Goods and Services

FOOD PRODUCTION

Grasslands are central to world food production. Historically, grasslands have been the ecosystem most extensively transformed to agriculture; they are the original source of many food crops and a continuing source of genetic material to improve modern crops. But grasslands are also major suppliers of food and income in the form of meat production from livestock. This is particularly important for rural populations. For example, in Africa, where rural populations are substantial, grasslands often support high livestock densities (the number of livestock raised per hectare) and are responsible for most of the continent's beef production (Box 2.33 Rangelands in Africa).

How much meat do grasslands currently produce? Global data on livestock production show more than 5 percent growth in world beef output in the last decade, to 54 million tons in 1998. Mutton and goat output increased even more–up 26 percent over the last decade to nearly 11 million tons. But such data do not provide a direct indicator of rangeland condition or its ability to support livestock. Meat production depends not only on grassland condition, but also on a range of other factors such as the availability of watering holes, dietary supplements, veterinary care, and the economic resources to acquire these things. In addition, some of the growth in meat production has come from the rapid rise in the use of feedlots (confined systems where animals cannot graze and are fattened on grain-based feeds to maximize weight gain). The popularity of intensive feedlot production is growing not only in developed countries where it is already common, but also in developing counties (Sere and Steinfeld 1996:40–41). It is not clear what implications the growing use of intensive livestock systems will have on grassland conditions, worldwide. Feedlots accounted for 12 percent of world beef and mutton production in 1996 (De Haan et al. 1997:53).

Information about livestock density is available for much of the world's grasslands and can provide a window on the grazing pressure grasslands face. However, like meat production, livestock density alone does not provide an accurate measure of the condition of the grassland system. Again, it is important to know how the livestock are managed–in particular, whether they are maintained in stable grazing systems, where livestock continuously graze a given parcel, or mobile grazing systems, where livestock are rotated over many different grazing lands. High livestock densities may indicate a highly productive system–one that effectively rotates cattle among grazing lands

(continues on p. 129)

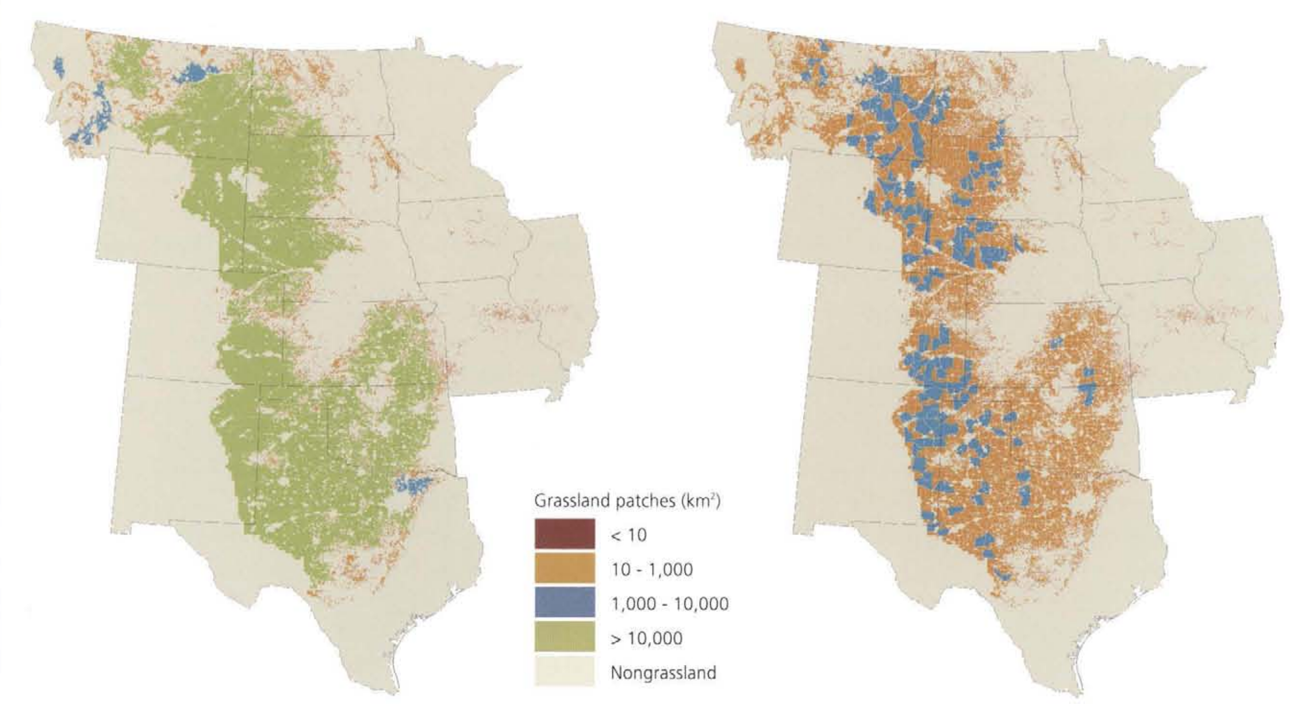
Box 2.32 Fragmentation of American Grasslands

Fragmentation of grassland ecosystems can compromise their ability to provide goods and services and jeopardize their biodiversity. Agriculture, urbanization, and road building are the primary human-caused sources of grassland fragmentation, but fencing and encroachment by woody vegetation can also have significant impacts.

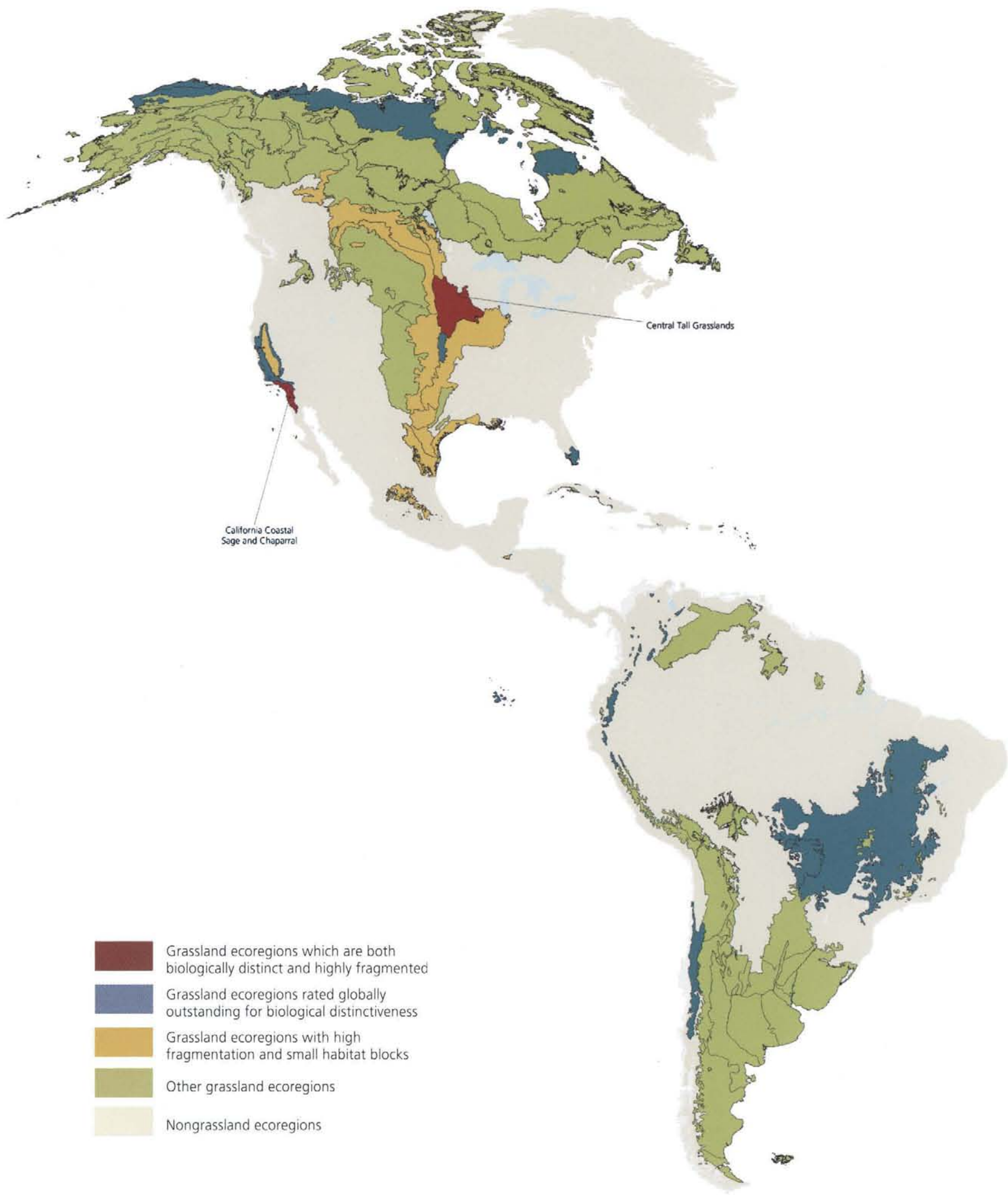
In the Western Hemisphere, the most fragmented grassland ecoregions are the intensively farmed areas of temperate and subtropical North America. The degree of fragmentation of the grasslands of the Great Plains region in the United States has been exacerbated by extensive road construction. If the road network is not taken into account, 90 percent of grassland area is composed of blocks 10,000 km^2 or more in extent. With roads factored in, however, no continuous blocks of this size remain, and 70 percent of the total area is made up of patches less than 1,000 km^2.

Grassland Blocks in the Great Plains, Excluding Roads

Grassland Blocks in the Great Plains, Including Roads



Fragmented Grassland Ecoregions of the Americas

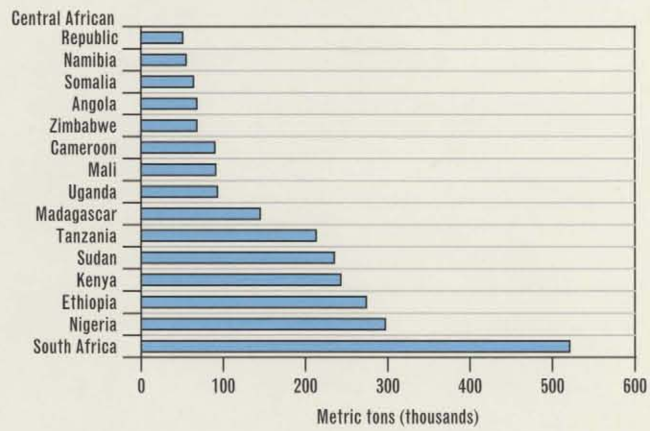


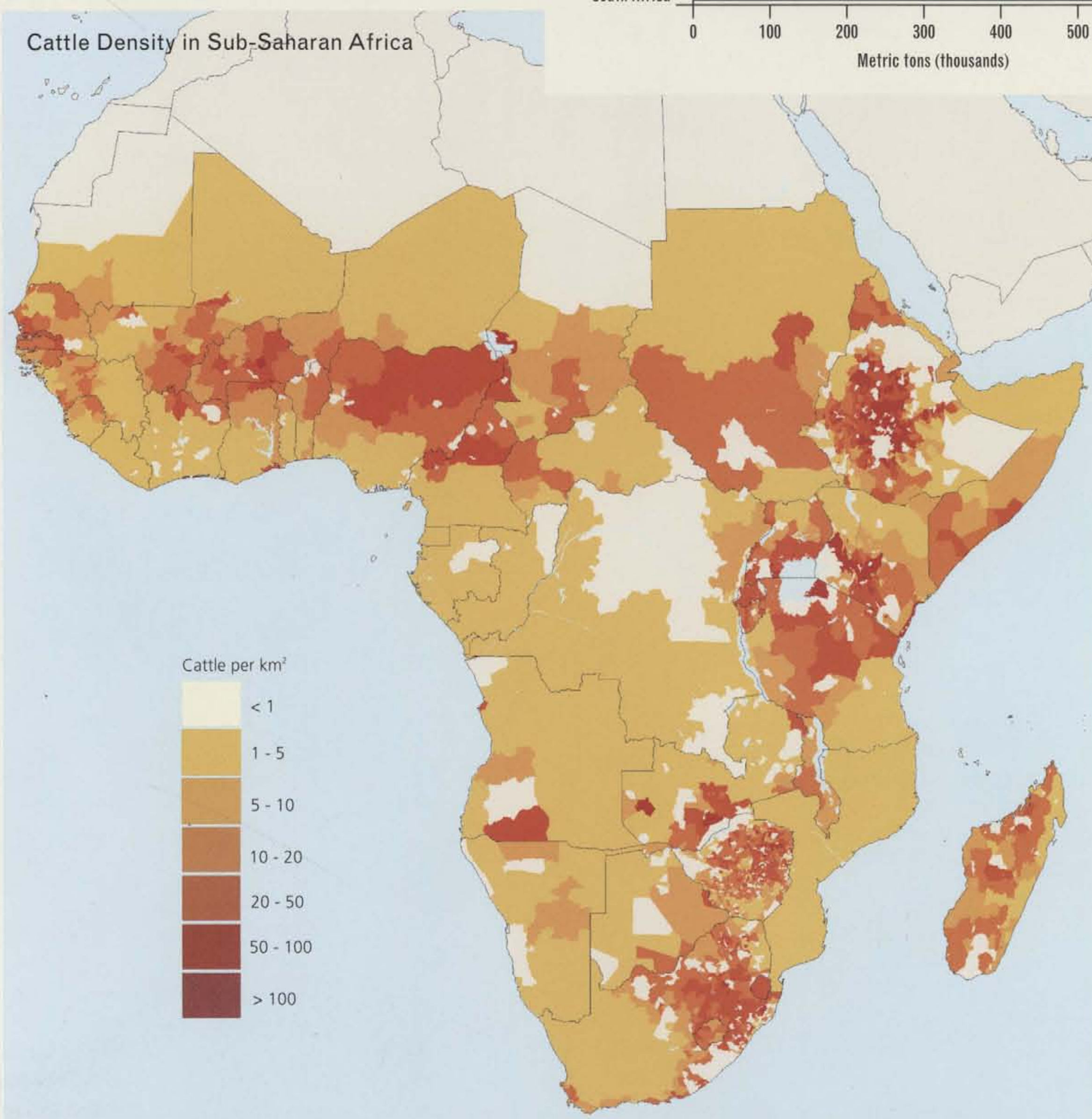
Sources: White et al. [PAGE] 2000. Maps of the Great Plains are based on Global Land Cover Characteristics Database Version 1.2 (Loveland et al. 2000). Map of the Americas is based on the WWF Conservation Assessment for North America, Latin America, and the Caribbean.

Box 2.33 Rangelands in Africa

Grasslands support some of the highest concentrations of cattle in Africa, where many rural populations depend on livestock for sustenance. High densities of livestock may indicate productive, well-managed systems or overstocked, poorly managed ones. Evidence of soil degradation often signals poor management because overstocking of herds diminishes vegetative cover and contributes to erosion. In Africa, a quarter of the susceptible drylands are now degraded, and much of that 320-Mha area is considered to be strongly or extremely degraded. The capacity of African grasslands to continue to support livestock production appears to be poor.

Beef and Veal Production in Sub-Saharan Africa, 1998





Source: White et al. [PAGE] 2000. Map is based on International Livestock Research Institute (1998). Table is based on FAOSTAT (1999).

and spreads the grazing pressure so that overgrazing does not occur. But high livestock densities could just as easily indicate an overstocked grassland, prone to overgrazing, and with production likely to decrease in subsequent years.

The importance of the livestock management system—mobile or static—is clear from a study of six grassland-rich regions of Mongolia, Russia, and China. In many parts of the study area, more recent sedentary methods of raising livestock using enclosed pastures have replaced older grazing systems more characterized by mobility, rotating livestock over multiple, sometimes widely separated, grazing sites. Comparisons among the regions indicate that the highest levels of grassland degradation are found where livestock mobility is lowest and static production systems have become the norm (Sneath 1998:1148) (see also Chapter 3 Sustaining the Steppe: The Future of Mongolia's Grasslands).

One of the most visible and useful indicators of degradation of grazing lands is soil erosion. High densities of livestock or poor management of herds diminish vegetative cover and contribute to erosion. This eventually will reduce the productivity of the grassland, although some areas with deep soils can withstand high rates of erosion for considerable time. Accordingly, information about soil condition provides a good indicator of the capacity of grassland ecosystems to sustain food production over the long term.

GLASOD provides the only source of comprehensive global information about soil loss for regions with extensive grasslands (Oldeman et al. 1991). The GLASOD study did not explicitly report on grassland areas as defined in the PAGE study; however, it did report data on the world's drylands, where grasslands are a major presence. Drylands in the arid, semiarid, and dry subhumid zones are considered particularly susceptible to soil degradation, and these susceptible drylands constitute 55 percent of grasslands as defined in PAGE. GLASOD found that slightly more than 1 Bha, or 20 percent, of all susceptible drylands globally have been degraded by human activity (Middleton and Thomas 1997:19). Water erosion is responsible for 45 percent of this damage and wind erosion 42 percent (White et al. [PAGE] 2000; Middleton and Thomas 1997:24).

Regionally, Asia has the largest area of degraded drylands: 370 Mha, or 22 percent of susceptible drylands. However, a larger fraction of Africa's susceptible drylands are degraded (25 percent, or 320 Mha) and—perhaps more critical—a higher proportion of these degraded areas are classified as "strongly degraded" and "extremely degraded"—GLASOD's severest degradation categories (Middleton and Thomas 1997:19). Elsewhere in the world, although the absolute area of degraded drylands is small, the proportionate area is sometimes large. In Europe, 99.4 Mha, or 32 percent, of the dryland area is degraded to some extent. North America, Australia, and South America have 11, 15, and 13 percent of susceptible dryland soils degraded, respectively (Middleton and Thomas 1997:19).

The Bottom Line for Food Production. Worldwide production of beef, mutton, and goat meat has never been higher. However, this reflects more the intensification of meat production into feedlots than an increase in grasslands' ability to support livestock. In fact, data on soil degradation in the world's susceptible drylands suggest that the capacity of grasslands to continue to support livestock production over the long term appears to be declining in many areas, with 20 percent of the world's susceptible drylands being degraded.

BIODIVERSITY

As in other ecosystems, grassland biodiversity supplies direct goods—game species, medicinal plants, tourism, and genetic material for breeding purposes, to name a few—and is also a critical factor underlying the capacity of grasslands to provide other goods and services. Many grasslands contain a rich assemblage of species—often species found in no other ecosystems. For example, PAGE researchers found that 19 percent of the world's recognized Centers of Plant Diversity (regions that contain large numbers of species, especially species found in only limited areas) are located in grasslands (White et al. [PAGE] 2000). Similarly, grassland areas contain 11 percent of the world's endemic bird areas (areas encompassing the ranges of two or more species that have relatively small breeding ranges).

The importance of grasslands for biological diversity is also evident from the biological distinctiveness index developed by WWF. This index considers species richness, species endemism, rarity of habitat type, and ecological phenomena, among other criteria. For North America, 10 of 32 regions rated as "globally outstanding" for biological distinctiveness are in grassland ecosystems. In Latin America, 9 of 34 of these regions are in grasslands (Dinerstein et al. 1995:21; Ricketts et al. 1997:33).

Information about the actual condition of grassland biodiversity is far less common than information about pressures threatening biodiversity, such as habitat loss and fragmentation. For this reason, the PAGE study does not include globally comprehensive measures of grassland biodiversity condition. However, PAGE researchers did draw on more restricted regional studies that can provide insight into grassland biodiversity trends.

For grasslands in North America, the North American Breeding Bird Survey provides 30-year population trends for a wide range of bird species. Survey data from 1966 to 1995 for bird species that breed in grasslands show declines throughout most of the United States and Canada. In contrast, a recent study of the Serengeti region of East Africa concluded that significant changes have not occurred in resident herbivore densities in the last 20 years. In areas close to protected area boundaries but less accessible to vehicle patrols, wildlife populations that were already low experienced declines (Campbell and Borner 1995:141).

The number and abundance of introduced species is also an indicator of biodiversity condition. Information about introduced species has never been assembled globally, but studies in North America are illustrative of nonnative species invasions in the grasslands there. The United States Congressional Office of Technology Assessment estimated that at least 4,500 nonnative species have been introduced into the United States, with approximately 15 percent causing severe harm (USCOTA 1993:3–5). A WWF study of the distribution of nonnative plant species in North America shows that at least 10 percent of the species in all ecoregions (ecologically distinct regions) within the Great Plains are nonnative, and more than 20 percent are nonnative in the California Central Valley Grasslands (Ricketts et al. 1997:83).

In the face of significant pressures on biodiversity and declining condition at a regional level, protected areas can play a pivotal role in maintaining at least samples of the natural diversity of species and habitats in grasslands. However, PAGE researchers determined that less than 15 percent of the world's protected areas consist of at least 50 percent grassland. Protected grasslands total 2.1 million km^2–about 4 percent of global grassland area (White et al. [PAGE] 2000).

The Bottom Line for Biodiversity. Direct measurements of biodiversity condition in grasslands are sparse. However, where information is available it shows that serious problems of species introductions are common and that populations of many native species are dropping. This suggests that, at least regionally, the capacity of grasslands to support biodiversity is decreasing. Indeed, the extensive conversion of grasslands to agriculture and urban areas and the growing degree of fragmentation suggest that many grassland ecosystems may already be unable to provide goods and services related to biodiversity. And, of the many areas that have been identified as still containing outstanding grassland biodiversity, few are monitored or protected by legislation or maintenance programs.

CARBON STORAGE

How the world's grasslands are managed will have a significant influence on atmospheric carbon concentrations. PAGE researchers calculated that the soil and vegetation in grasslands worldwide currently store 405–806 GtC–about 33 percent of the total carbon stored in terrestrial ecosystems. The amount of carbon stored in grasslands is about half the amount stored in forest ecosystems, even though the total area of grasslands is nearly twice as large.

Unlike tropical forests, where carbon is stored primarily in above-ground vegetation, soils store most of the carbon in grasslands (Middleton and Thomas 1997:141). In grasslands large amounts of carbon are deposited into the soil as organic litter and secretions from roots, and as nutrients for microbial organisms and insects. For example, in one savanna in South Africa, soil organic matter accounts for approximately two-thirds of the total carbon pool of about 9 kg C/m^2 (Scholes and Walker 1993:84).

A variety of human activities can disturb the carbon storage capacity of grasslands. When grasslands are converted to croplands, the removal of vegetation and subsequent cultivation reduces surface cover and destabilizes soil, leading to the release of organic carbon. Degradation of grass cover in drylands can also be a significant source of carbon loss in grasslands, as can the widespread practice of burning grasslands to improve their pasture value (Andreae 1991:5; Sala and Paruelo 1997:238). Even the growing threat of invasive species in grasslands may bode ill for carbon storage. For example, recent experiments suggest that crested wheatgrass–a shallow-rooted grass introduced to North American prairies from North Asia to improve cattle forage–stores less carbon than native perennial prairie grasses with their extensive root systems (Christian and Wilson 1999:2397).

On the other hand, programs aimed at curbing land degradation and rehabilitating grassland cover could increase carbon storage in the world's grasslands. Projections for carbon storage in the world's drylands from 1990 to 2040 show a difference of 37 gigatons in carbon emissions between a "business as usual" scenario where current degradation patterns continue, and a sustainable management scenario if programs for land rehabilitation are implemented (Ojima et al. 1993:108).

The Bottom Line for Carbon Storage. Although they store less carbon than world forests, grasslands do store approximately 33 percent of all carbon stored in terrestrial ecosystems, mostly in the soil. Thus the potential for soil degradation to decrease carbon storage in grasslands is significant. Current practices of grassland conversion and degradation of dry grassland areas are reducing the carbon storage potential in many regions of the world, especially the arid zones.

TOURISM

Grasslands provide important cultural, aesthetic, and recreational services. Many grasslands serve as choice hiking, hunting, and fishing areas, while other grasslands are sites of historical importance and religious and ceremonial activities. For example, Native American religious, ceremonial, and historical sites have been preserved in many places throughout the prairies of the United States (Williams and Diebel 1996:27).

The economic contribution of the recreational services provided by grasslands can be significant. For example, in Tanzania, gross earnings from tourism related to game hunting were $13.9 million in 1992–93, a threefold increase over 1988 (Planning and Assessment for Wildlife Management 1996:78). Similarly, total annual earnings in Zimbabwe's hunting industry grew from approximately $3 million in 1984 to close to $9 million in 1990 (Price Waterhouse 1996:85).

Other developing countries with extensive grasslands have also shown tremendous growth in international tourist receipts (income from visitors coming from out of the country) over the 10-year interval between 1985–87 and 1995–97. In Tanzania, for example, international tourist receipts rose 1441 percent, while in Ghana and Madagascar, receipts increased more than 800 percent (Honey 1999:368–369). Of course, not all this tourist growth necessarily corresponds to grassland tourism, but in some countries, such as Kenya, grasslands and their wildlife are clearly the most popular tourist destination (Honey 1999:329).

Given the growing importance of tourism as an income source, it is important to recognize that tourism also can become a pressure on ecosystems. Wildlife-seeking hunters and camera-wielding tourists can disturb wildlife, degrade grasslands with off-road excursions, pollute grasslands with a variety of pollutants including trash, and increase consumption of water and other resources in fragile areas. All these can impair the long-term ability of grassland ecosystems to provide the beauty and biodiversity that draws tourists in the first place. Analyses of tourist impacts in Kenya, Tanzania, and South Africa show mixed impacts in parks and other grassland areas, with damage mostly confined to heavily visited areas so far (Honey 1999:256).

Poaching is another modifying and degrading influence on grasslands that continues to be a problem in several African countries. In Kenya, elephant populations dropped 85 percent between 1975 and 1990 to approximately 20,000, and the rhinoceros population declined by 97 percent to less than 500 animals (Honey 1999:298).

The Bottom Line for Tourism. Growth in tourist numbers and tourism receipts in grassland-rich countries speaks to the significant economic contribution of grasslands tourism. But it is difficult to evaluate the present quality and long-term prognosis for grasslands tourism because of the lack of consistent, comprehensive data on wildlife exploitation, tourist impacts, and the size and quality of trophy animals, among other indicators. Nonetheless, the continued conversion of grasslands to agriculture and urban areas, increased fire frequency, the spread of invasive species, and the impacts of tourism itself suggest a potential decline in the capacity of grasslands to maintain tourism and recreational services over the long term.