# Rangeland Resource Trends in the United States

John E. Mitchell

*A Technical Document Supporting the 2000 USDA Forest Service RPA Assessment*

U.S. Department of Agriculture Forest Service

Mitchell, John E. 2000. Rangeland resource trends in the United States: A technical document supporting the 2000 USDA Forest Service RPA Assessment. Gen. Tech. Rep. RMRS-GTR-68. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 84 p.

Keywords: rangeland health, rangeland management, weeds, grazing, livestock, sustainability, Conservation Reserve Program

## Abstract

This report documents trends in America's rangelands as required by the Renewable Resources Planning Act of 1974. The Forest Service has conducted assessments of the rangeland situation for 30 years. Over this period, rangeland values and uses have gradually shifted from concentrating upon forage production and meeting increasing demand for red meat to a more broad-based understanding under a framework of sustainable resource management. The total extent of rangeland will likely continue a trend of slow decline, but any changes will be small in relation to the total U.S. grazing land base of about 800 million acres. Lands enrolled in the Conservation Reserve Program are not expected to affect this trend. Data from various sources indicate that range condition has been fairly static over the past decade. Non-indigenous weed invasions have offset advances in rangeland health. Regardless, the productive capacity of U.S. rangelands is not expected to degrade because of slowly decreasing livestock utilization and possible advances in biotechnology. Trends in the number of people with adequate technical skills to manage rangelands and conduct research need closer attention.

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# Rangeland Resource Trends in the United States: A Technical Document Supporting the 2000 USDA Forest Service RPA Assessment

**John E. Mitchell**

## Contents

# Executive Summary

## Chapter 1: Introduction

This Range Assessment, like those preceding it, addresses contemporary topics while continuing a baseline appraisal of the central theme for all range assessments: the demand for and supply of forage in the United States. It examines both anticipated supply and future demand from a different perspective, however. The U.S. Department of Agriculture no longer maintains a model system with a 50-year outlook like that used in the previous two rangeland assessments. Therefore, an alternative approach, scenario analysis, was selected to project forage demand, and is described in a separate report (Van Tassell et al. 1999). Supply projections are still tied to land use changes, but increases in rangeland resulting from conservation programs are no longer anticipated (Chapter 2: Extent of Rangelands). Advances in technology are not expected to significantly change the overall forage supply (Chapter 4: Maintenance of Productive Capacity), although this opinion is not unanimous. Van Tassell et al. (1999) concluded that changes in forage production technology would enhance the use of some grazing lands, especially in the South.

Four Assessment Regions are used to describe data and other information on U.S. rangelands: the Pacific Coast (PC), Rocky Mountain (RM), Northern (NO), and Southern (SO).

### *Criteria and Indicators of Sustainability*

Determining the supply of natural resource outputs at a national level requires an evaluation of factors influencing their level of expression in the environment. One effort for identifying criteria and indicators (C&I) of sustainable forests at a national scale, the Montreal Process, has become widely recognized. Moreover, the concept of using C&I as factors for evaluating all facets of sustainability, including resource supplies, is being increasingly accepted. The Montreal Process has converged on 7 criteria and 67 indicators for the sustainability of temperate and boreal forests, ultimately recognized in the Santiago Declaration of 1995.

Work is presently in progress to evaluate the applicability of the Montreal Process C&I to rangelands. At least four criteria (Conserving biological diversity, maintenance of productive capacity of rangeland ecosystems, maintenance of rangeland health and vitality, and conservation and maintenance of soil and water resources) are expected to relate directly to rangeland resource outputs. The other three criteria contain indicators having important, if less direct, impacts on the supply and demand for rangeland resources. Chapter 2 (Extent of Rangelands), Chapter 3 (Rangeland Health), and Chapter 4 (Maintenance of Productive Capacity) are written with criteria of the Montreal Process in mind.

## Chapter 2: Extent of Rangelands

Area of rangeland is an indicator of ecosystem diversity at a national scale. Although more than half of all the ecosystem types determined to have lost more than 98 percent of their pre-settlement extent are grasslands or shrublands, this total is weighted heavily by the near-total disappearance of tallgrass prairie and extensive conversions of the mixed-grass plains and Palouse prairie to agricultural use prior to the 1930's. There is no indication that endangered rangeland ecosystem types are now being lost except for desert grasslands.

The amount of grazing land and rangeland in the United States is expected to continue to decline slowly over the next 50 years. However, land use shifts away from grazing use will be much greater in areas of more rapid population increases and concomitant appreciating land values. Whether the Rocky Mountains and their foothills will continue to dominate locations of high immigration by the year 2050 is unknown. Research supporting forage demand projections, however, suggests that changes in land use will decrease the amount of land available for grazing to a greater extent in a consolidated Pacific Coast and Rocky Mountain Assessment Region than either the North or South Assessment Regions throughout the foreseeable future.

## Chapter 3: Rangeland Health

Rangeland health is connected to the broader concepts of sustainability and sustainable management. Three indicators gauge the maintenance of ecosystem health under the Montreal Process: Area and percent of rangeland affected by processes or agents beyond the ranges of historic variation; area and percent of rangeland subject to specific levels of air pollution or ultraviolet B that may cause negative ecosystem impacts; and area and percent of rangeland with diminished biological components indicative of changes in fundamental ecological processes.

Invasions of exotic species, fire, drought, and grazing are examples of agents and processes that have apparently occurred beyond their range of historic variation on U.S. rangelands during the past 150 years. Fire is a natural and important component of many U.S. rangelands, but fire prevention and suppression programs over the past 70 years have resulted in a major shift in fire frequencies. Expansion of non-indigenous weeds and changes in grazing have also been considered in this chapter. Measured at the site level, range condition has remained fairly static since the last assessment.

A number of indicators have been developed as part of the Montreal Process for evaluating how well a nation maintains its soil and water resources. Among them are the area and percent of rangeland with significant soil erosion, and percent of stream length in which stream flow and timing have significantly deviated from the historic range of variation. Although there are national data sets for soils, water quality, and stream flow, they have such varying degrees of coverage, compatibility, and recency that comprehensive analyses of them are problematic. The Proper Functioning Condition (PFC) approach for rating the health and functioning of riparian zones could well serve as an adequate method for reporting the percent of stream reaches with abnormal stream flow and timing.

The vast expanses and remoteness of rangelands, both in the U.S. and globally, make assessing these indicators of health and vitality difficult. No national monitoring framework is in place to collect data on long-term or episodic processes and agents over time. The best data available for the ecosystem health criterion may be for its second indicator because of national networks to monitor air quality.

There are no hard rules for summarizing these or other criteria to determine rangeland health. Individual conclusions will vary from person to person and organization to organization. Thus any collective overview can only be reached through values and objectives of society as expressed primarily through society's refinement process of laws and regulations.

### Chapter 4: Maintenance of Productive Capacity

Montreal Process indicators for productive capacity address the area of rangeland and total biomass available for grazing, and the annual removal of forage compared to that determined to be sustainable. These indicators are difficult to monitor and document on a national scale, and efforts have not been adequate. However, given the projection that livestock utilization of grazing land will decrease in the Pacific Coast, Rocky Mountain, and Northern Assessment Regions and not change significantly in the Southern, we can expect that the overall U.S. productive capacity will not be degraded. The slow decline in grazing land base may be offset, in part, by equally slow increases in rangeland health and advances in grazing technology. Projected slowly rising consumption of red meat should not create extensive new demands for forage. For that and other reasons, lands in the Conservation Reserve Program, described in Chapter 2, are not expected to have even a moderate effect on livestock numbers. They have been shown to have a positive influence on some wildlife species at the regional level, however. A proliferation of non-indigenous weeds, explained in Chapter 3, could feasibly impact the productive capacity of rangeland, regionally. If demands for forage ever exceed supply, however, market forces should prompt shifts in land use from agriculture to grazing land, such as described in Chapter 2.

Since there is no reason to expect significant increases in the rangeland base, advances in technology affecting productivity of rangeland forage species, or restoration of rangeland health, we must conclude that the supply of forage in the United States is not likely to change significantly over the next few decades. The country's productive capacity should remain adequate to promote sustainable management of U.S. rangelands, however.

### Chapter 5: Institutional Framework for Rangeland Conservation and Sustainable Management

This chapter focuses on the probability of maintaining a critical mass of people with adequate technical skills to properly manage rangelands, educate students, and conduct needed research and development. The outlook is not optimistic. Although job opportunities have diversified, as have university curricula, trends in numbers of students have been mixed. Numbers of students training to be researchers have declined. Numbers of persons employed in rangeland management by the Forest Service and Bureau of Land Management have declined significantly, while the Natural Resources Conservation Service has held constant.

An aging population of rangeland managers and educators has significant implications for our ability to maintain that critical mass of people with adequate technical skills.

## Acknowledgments

The rangeland component of the 1999 RPA range assessment was begun under the capable direction of Linda A. Joyce, Project Leader, Rocky Mountain Research Station. This assignment was passed to the present author in the fall of 1995. Dr. Joyce was instrumental in facilitating a smooth and effective transition at that time. Since then, she has never hesitated to share her experience and insights concerning all aspects of preparing an assessment document. These contributions are gratefully recognized.

Much of the data acquisition and summarization was carried out by Alicia Goddard, a Colorado State University graduate student employed by the Rocky Mountain Research Station as a rangeland management specialist. Her work was an essential component of updating the 1989 RPA range assessment. In addition, Ms. Goddard conducted the analyses relating to demographic and land-use changes on U.S. rangelands.

Projections of demand for forage were estimated by a team of three range economists led by Drs. E.T. Bartlett, Professor of Rangeland Ecosystem Science, Colorado State University, and Larry W. Van Tassell, Professor of Agricultural Economics, University of Wyoming (who now is Head, Department of Agricultural Economics and Rural Sociology, University of Idaho). Dr. Neil Rimbey, Extension Professor of Range Economics, University of Idaho, worked closely with them. Their work, which influenced the contents of this document, is published in a separate report (Van Tassell et. al. 1999).

Investigations concerning the extent and distribution of non-indigenous weeds were led by Dr. George Beck, Professor of Weed Science, Colorado State University, and his graduate student, Ms. Suellen May. A review and analysis of rangeland biodiversity was carried out under the guidance of Dr. Dan Milchunas, Research Associate in Rangeland Ecosystem Science, Colorado State University. The results of his research has been submitted for publication elsewhere.

I am grateful to Forest Service range management staff officers for data and valuable advice. Included in this group are Rita Beard, Van Elsbernd, and Jim Montoya in Fort Collins; Daryl Herman and Dr. Larry Bryant in the Washington Office; and regional staff officers Jim Olivarez, Bruce Fox, Charlie Richmond, Dave Stewart, John Conner, Bob Hamner, Curt Johnson, Dick Lindenmuth, and Levester Pendergrass. Many others at the Forest and District levels helped provide needed information. Dr. Alison Hill, National Grassland Ecologist, served a valuable role as a liaison with the Vegetation Management and Protection Research Staff.

Other agencies contributed data and results of other assessments for my use. I am especially appreciative to Steve Brady, Natural Resources Conservation Service (NRCS), for facilitating access to and analysis of the National Resources Inventory data. Tom Roberts, Bureau of Land Management, was directly involved in helping appraise the breadth of pinyon-juniper expansion; he also helped in other ways.

Finally, the RPA specialists in Fort Collins, Drs. Curt Flather, Deborah Shields, John Hof, and Tom Brown, made preparation of the rangeland assessment easier by providing guidance and sharing information. Dr. Linda Langner, WO RPA staff, was liaison officer for this assignment, and it could not have been completed without her direction. Mark Delfs, RPA Branch Chief for Assessments and Analysis, facilitated after Dr. Langner was called to another assignment. Dr. H. Fred Kaiser, Jr. and Dr. Dave Darr provided continual support and counsel. So, in reality, the following document represents a group effort with many contributors.

# Chapter 1: Introduction

The status of rangelands in the United States has been of continual interest to the Congress and American people since the western states were occupied by Europeans. Until 1854, the issue for the federal government was one of acquisition. A decade later, however, the Homestead Act of 1862 marked the beginning of an era of land disposal. This western expansion for minerals, forage, and timber was considered our country's "manifest destiny" (Clawson 1983).

During the 100 years following the Civil War, U.S. rangelands were almost exclusively used for livestock grazing. During the 1880's, the number of cattle in the 17 western states proliferated almost six-fold from 4.5 million head to nearly 27 million head (Poling 1991). This was the high water mark of the prominent cattle barons financed by European capital (Mitchell and Hart 1987). At the same time, the number of domestic sheep was also multiplying—from less than one million head in 1850 to 20 million head by 1890 (Stoddart and Smith 1943).

The first national problem involving rangelands originated from the joint effects of land disposal and rapidly increasing livestock numbers. Large cumulative areas were awarded for railroad expansion and to states when they jointed the Union. Counting Alaska, 17 percent of the total state land area of the 30 states receiving land grants was obtained from the federal government; for the 16 western states (Texas received no land), the figure was more than 91 million acres or almost 10 percent of their cumulative area (Public Land Law Review Commission 1970).

The Homestead Act of 1862 was followed by the Enlarged Homestead Act of 1909 (which allowed settlers to claim 320 acres) and the Stock Raising Homestead Act of 1916 (which provided 640 acres). In total, about 285 million acres were claimed under the Homestead Acts (Ross 1984). All lands containing water and good grazing were occupied during this era. Even a section of land was insufficient for homesteaders to make a living throughout much of the West, however, so grazing started on the public domain (Carpenter 1981).

## Early Assessments

By 1934, the United States was facing a crisis on the public domain and, to a lesser extent, on National Forest reserves. The crisis was caused by the depression, drought, and conflicts between cattle and sheep interests in conjunction with severe depletion of the rangeland resource. States tried to regulate grazing within their borders, but the migratory nature of sheep operations compared to the spatially fixed character of cattle ranches precluded solutions at the state level (Carpenter 1981). The result was passage of Senate Resolution 289 in the 74th Congress. The resolution read:

> *"Whereas large parts of the western range have been subject to unrestricted use since settlement and are commonly believed to be more or less seriously depleted; and whereas the range resource constitutes one of the major sources of wealth to the Nation; and whereas the Department of Agriculture has through many years of research and of administration of the national forests accumulated a large amount of information on the original and present condition of the range resource, the factors which have led to the present condition, and the social and economic importance of the range and its conservation to the West and to the entire United States: Therefore, be it resolved that the Secretary of Agriculture be ... requested to transmit to the Senate at his earliest convenience a report incorporating this information, together with recommendations as to constructive measures."*

The Secretary of Agriculture (1936) subsequently submitted Senate Document 199, entitled "The Western Range." In it, he highlighted several elements, including the following:

- Of the 728 million acres of rangeland, more than 99 percent "is available for livestock grazing."
- Much of the range, especially in the Southwest, is in severely depleted condition (figure 1.1).
- A "maladjustment" to rangeland use has been the attempt to use more than 50 million acres for dryland farming.
- At least 589 million acres of rangeland is eroding excessively, thereby reducing soil productivity and impairing watershed function.

Box (1990) summarized findings pertaining to rangeland depletion contained in the Senate Document 199 report in two tables, reproduced here. They showed the National Forest reserves to be in better condition than private, state, and public domain lands (table 1.1), and that National Forest land was in an improving trend while the other three categories were in decline (table 1.2).

World War II interrupted conservation priorities in the United States. High priority was placed on producing red meat, wool, and leather for the war effort (Wasser 1942).

**Table 1.1—**Depletion of U.S. rangelands by ownership in 1935, taken from Senate Document 199 by Box (1990).

| Ownership | Percent of Land by Depletion Class[1] | | | |
|---|---|---|---|---|
| | Moderate (0–25%) | Material[2] (26–50%) | Severe (51–75%) | Extreme (76–100%) |
| Federal | | | | |
| National Forests | 45.5 | 40.0 | 12.0 | 2.5 |
| Public Domain | 1.5 | 14.3 | 47.9 | 36.3 |
| Indian Lands | 6.6 | 35.8 | 54.0 | 3.6 |
| Other Federal | 2.0 | 21.2 | 50.1 | 26.7 |
| State and County | 7.1 | 47.4 | 36.8 | 8.7 |
| Private | 11.7 | 36.9 | 36.4 | 15.0 |

[1] *Referred to depletion of forage value in relation to "virgin" range.*
[2] *Substantial or noticeable.*

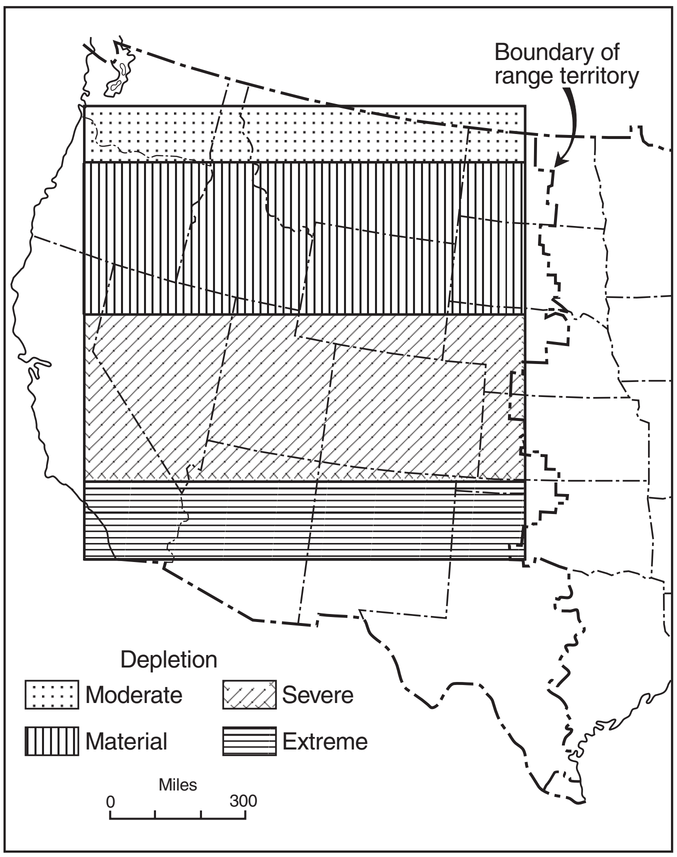



**Fig. 1.1—**Range depletion classes presented in Senate Document 199 (1936). Of the depletion classes, material (26–50 percent) and severe (51–75 percent) covered more than 70 percent of the entire "range area." Nearly 120 million ac. was shown in the extreme (76–100 percent) depletion class. Of the 95 million ac. in the moderate (0–25 percent) depletion class, probably not more than half was estimated to be in "thoroughly satisfactory" condition.

**Table 1.2—**Trends in range forage condition between 1905 and 1935, taken from Senate Document 199 by Box (1990).

| Ownership | Percent of Land by Trend Class | | |
|---|---|---|---|
| | Improved | Declined | Unchanged |
| Federal | | | |
| National Forests | 77 | 5 | 18 |
| Public Domain | 2 | 93 | 5 |
| Indian Lands | 10 | 75 | 15 |
| Other Federal | 7 | 81 | 12 |
| State and County | 7 | 88 | 5 |
| Private | 10 | 85 | 5 |

The next national assessment of rangelands, along with all other public lands not set aside for Indian reservations, was initiated in 1964 by the passage of Public Law 88-606, which established the Public Land Law Review Commission under the chair of Rep. Wayne Aspinall of Colorado. Its purpose was to review the effects of existing law and policy to determine whether U.S. public lands were providing "the maximum benefit for the general public."

When the Public Land Law Review Commission published its report to the President and Congress in 1970, the section of the report addressing rangelands emphasized the importance of forage coming from public lands (figure 1.2). Although public lands accounted for only 3 percent of all forage consumed by livestock in the United States during the 1960's, they supplied approximately 12 percent of the forage in the western range states. In these states, forage from public lands was seen to play a significant role in local economies, and increased funding to improve rangeland health was recommended. Cattle and sheep on public rangelands were seen as "an accepted

**Table 1.3—**Principal conservation laws passed during the 1970's that pertain to rangelands.

| | |
|---|---|
| National Environmental Policy Act of 1969 | Requires consideration of environmental impacts of Federal actions. |
| Wild Horses and Burros Protection Act | Protects wild horses and burros. |
| Endangered Species Act of 1973 | Provides a means for protecting/restoring threatened and endangered species. |
| Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) | Requires renewable resources assessment and program. |
| Eastern Wilderness Act | Promotes incorporating eastern public lands into the Wilderness system. |
| Federal Noxious Weed Act of 1974 | Controls dissemination of noxious weeds. |
| Federal Land Policy and Management Act of 1976 (FLPMA) | Retains remaining public domain lands in public ownership. Acts as organic act for the Bureau of Land Management. |
| National Forest Management Act of 1976 | Amends and expands RPA. |
| Soil and Water Resources Conservation Act of 1977 | Requires a recurring appraisal of all private lands and authorizes a national soil and water conservation program. |
| Forest and Rangeland Renewable Resources Research Act of 1978 | Expands research activities to encompass natural resource issues on a global scale. |
| Public Rangelands Improvement Act of 1978 | Avows policy of monitoring and improving rangeland conditions; sets grazing fee policy. |
| Archaeological Resources Protection Act of 1979 | Protects archaeological resources and sites on public and Indian lands. |

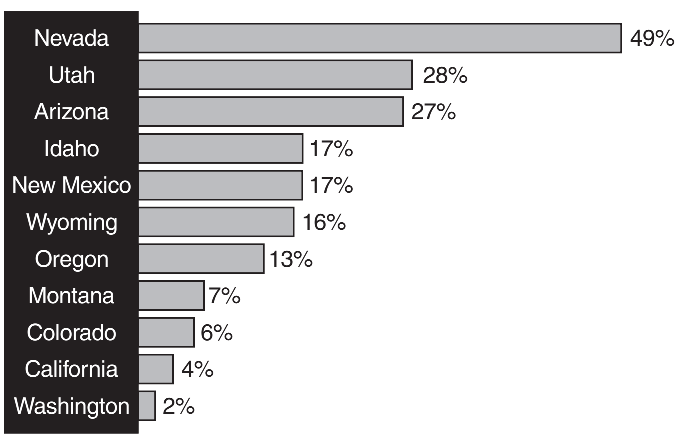



**Fig. 1.2—**The importance of western public rangelands in the 1960's (Public Land Law Review Commission 1970).

feature of the scenery and environment" (Public Land Law Review Commission 1970).

From a legislative context, the 1970's could be considered the decade of the environmental movement. The Wilderness Act was enacted in 1964. Then, starting in January 1970 with the National Environmental Policy Act of 1969, no fewer than 12 major environmental laws affecting the conservation and management of U.S. rangelands were signed into law during the following 10 years (table 1.3). Among such laws were the Resources Planning Act of 1974 (RPA) and the National Forest Management Act of 1976 (NFMA) which called for a recurring assessment of America's forest and rangeland situation.

The first comprehensive assessment produced under the auspices of RPA/NFMA was published in 1980 (U.S. Department of Agriculture, Forest Service 1980). The chapter entitled "Range" defined rangeland in a manner that excluded improved pastures, cropland pasture, and grazed cropland because of they way these lands were managed—using agronomic instead of ecological means. Under this definition, 99 percent of the Nation's 650 million acres of rangeland were identified as being in the 17 western states. About two-thirds of these rangelands were estimated to be under private ownership.

The 1980 Assessment determined that 46 percent of rangelands in the conterminous 48 states were in fair to good condition. The authors noted the same general relationship between latitude and range condition reported in Senate Document 199 (Secretary of Agriculture 1936), except for Nevada which was deemed to be in better condition than expected (figure 1.1).

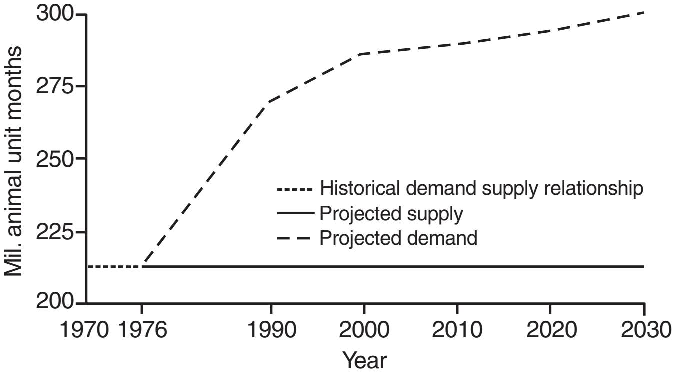



**Fig. 1.3—**Estimated increase in demand for rangeland forage, as presented in the 1980 RPA Assessment document (U.S. Department of Agriculture, Forest Service 1980).

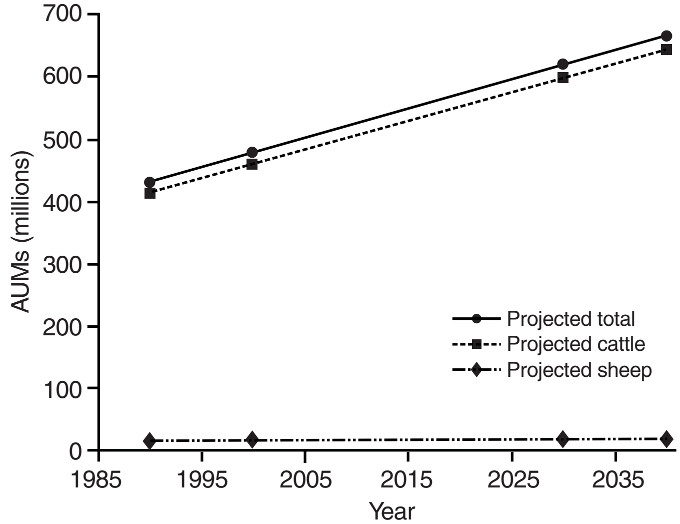



**Fig. 1.4—**Projected (1990–2040) U.S. consumption of grazed forages by cattle and sheep, as reported in Joyce (1989).

Projected demands for rangeland forage in the 1980 Assessment were derived from the National Interregional Agricultural Projections (NIRAP) system, developed by the USDA Economic Research Service.[1] The projections showed a logarithmic 40 percent increase between the years 1976 and 2030, from 213 million AUM's to 300 million AUM's (figure 1.3). Determined linearly over 55 years, such growth amounts to 0.62 percent per year. The principal factors driving the expansion in demand were forecasts for increased per capita demand for meat and increasing human populations (U.S. Department of Agriculture, Forest Service 1980).

A forecasted 40 percent increase in demand for rangeland forage influenced agencies and some corporate landowners to look for ways to increase forage supplies without causing adverse effects on other uses. For example, the Northern Region of the Forest Service concluded that it could only meet this anticipated increase in demand by expanding uses of transitory range[2] (Hardman 1979). Research relating to forage production on transitory range intensified (Eissenstat and Mitchell 1983).

The 1989 RPA Range Assessment established a new standard for projecting the derived demand for grazed forage in the United States (Joyce 1989, Gee et al. 1992). It expanded the definition of grazed forage to include, in addition to rangeland, irrigated and non-irrigated pastures and grazed crop residues. Thus, the estimated forage supply for 1985 contained in the 1989 Assessment was 431 million AUM's, substantially more than was projected for 1985 in the 1980 Assessment.

Also using the NIRAP system, but with revised estimates showing no increase in per capita meat consumption, the 1989 Range Assessment projected a linear increase in demand for grazed forage from 431 million AUM's to 665 million AUM's by the year 2040, a 54 percent increase (figure 1.4). This is equivalent to an annual increase in forage demand of 0.79 percent per year, a higher rate than projected in the 1980 Assessment. Nonetheless, based upon an anticipated expansion in the rangeland land base of 5 percent and advances in technology, the 1989 Assessment concluded that increased demand for grazed forages by cattle and sheep could be almost entirely accommodated by an expanding contribution from private lands (Joyce 1989).

In the decade since the last RPA Range Assessment (Joyce 1989), our society's values pertaining to public lands and natural resource management have begun to shift. Concepts such as sustainability, biodiversity, and the value of endangered species are having an increasingly larger influence upon management objectives (Salwasser et al. 1993). Policymakers, natural resource managers, and citizens, alike, are becoming aware of the importance of riparian zones (Chaney et al. 1990) and the cumulative effect caused by the spread of non-native plants (U.S. Congress, Office of Technology Assessment 1993). Amenity resources associated with rangelands are starting to be valued (Peterson et al. 1988). The present Range Assessment, like those preceding it, is structured to address contemporary topics while continuing a baseline appraisal of the central theme for all range assessments—the demand for and supply of forage in the United States It examines

*[1] Unpublished report: Quinby, William. 1989. Documentation of the NIRAP model. Washington, DC: U.S. Department of Agriculture, Economic Research Service, Natural Resource Economics Division. 29 p.*

*[2] Transitory range is forest land that normally does not produce forage, but which does so for a limited number of years following forest harvest or fire. See Basile and Jensen (1971), Lyon (1976), and Mitchell and Bartling (1991) for further discussion.*

**Table 1.4—**Montreal Process Criteria for the sustainable management of temperate and boreal forests (Coulombe 1995).

| | | |
|---|---|---|
| Criterion 1 | Conserving biological diversity. | (9 indicators) |
| Criterion 2 | Maintenance of productive capacity of forest ecosystems. | (5 indicators) |
| Criterion 3 | Maintenance of forest ecosystem health and vitality. | (3 indicators) |
| Criterion 4 | Conservation and maintenance of soil and water resources. | (8 indicators) |
| Criterion 5 | Maintenance of forest contribution to global carbon cycles. | (3 indicators) |
| Criterion 6 | Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies. | (19 indicators) |
| Criterion 7 | Legal, institutional and economic framework for forest conservation and sustainable management. | (20 indicators) |

both anticipated supply and future demand from a different perspective, however. The U.S. Department of Agriculture has dropped its support of the NIRAP system and no longer maintains a model with a 50-year outlook. Therefore, an alternative approach, scenario analysis, was selected to project forage demand, and is reported elsewhere (Van Tassell et al. 1999). Supply projections are still tied to land use changes, but increases in rangeland resulting from conservation programs are no longer anticipated (Chapter 2, Extent of Rangelands) and advances in technology are not expected to significantly change the forage supply per unit area (Chapter 4, Maintenance of Productive Capacity), except, perhaps, in the South (Van Tassell et al. 1999).

Four Assessment regions are used to describe data and other information on U.S. rangelands. They are the Pacific Coast (PC), Rocky Mountain (RM), North (NO), and South (SO) (figure 1.5). The Pacific Coast Assessment Region is further subdivided into the Pacific North (PN) and California (CA) Regions and the RM Assessment Region is subdivided into the Northern Rocky (NR) and Southwest (SW) Regions for some discussions.

## Criteria and Indicators of Sustainability

As explained by Joyce (1989) in the last RPA Rangeland Assessment, determining the supply of natural resource outputs at a national level requires an evaluation of factors influencing their level of expression in the environment. One effort for identifying criteria and indicators (C&I) for the sustainable management of temperate and boreal forests at a national scale, the Montreal Process, has become widely recognized. Moreover, the concept of using C&I as factors for evaluating all facets of sustainability, including resource supplies, is receiving increasing acceptance (Corson 1996).

The Montreal Process began with the 1992 United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992 (U.N. Conference on Environment and Development 1992). In addition to two treaty conventions, this conference produced three non-treaty agreements, including The Rio Declaration on Environment and Development and Agenda 21. The former presented a number of principles, one of which (Principle 4) stated, "In order to achieve sustainable development, environmental protection shall form an integral part of the development process." Specifically, the statement recognized that governments should be involved in devising scientifically credible C&I for the management, conservation, and sustainable development of forests. Agenda 21 was designed as a scheme for attaining sustainable development (Johnson 1993).

Following the Rio Conference, commonly called the "Earth Summit," Canada convened an international seminar on Sustainable Development of Boreal and Temperate Forests. It was held in Montreal in September 1993. The seminar specifically addressed the establishment of C&I for sustainable management of temperate and boreal forests, and provided the conceptual basis for subsequent work on the subject. From that conference came a working group, whose business became known as the Montreal Process, that developed a set of C&I for temperate and boreal forests.

The Montreal Process has converged upon 7 criteria and 67 indicators for the sustainability of temperate and boreal forests, ultimately recognized in the Santiago Declaration of 1995 (Coulombe 1995) (table 1.4). The Forest Service, in collaboration with other agencies and interest groups, is undertaking a extensive program to develop and implement a C&I framework that can be integrated into Forest Service strategic planning, annual performance planning, national assessments, and forest resource planning, inventory and monitoring (USDA Forest Service 1997).

Work is presently in progress to evaluate the applicability of these C&I to rangelands (Mitchell 1999a). Notwithstanding the results of the evaluation, at least four criteria (Conserving biological diversity, maintenance of productive capacity of rangeland ecosystems, maintenance of rangeland health and vitality, and conservation and maintenance of soil and water resources) are expected to relate directly to rangeland resource outputs. Criterion 7 (Legal, institutional, and economic framework for rangeland conservation and sustainable management) is also briefly considered in this report. The other two criteria contain indicators having important impacts on the supply and demand for rangeland resources; however, they are not considered directly. The relationships between the Montreal Process C&I are identified, where appropriate, throughout this assessment document.

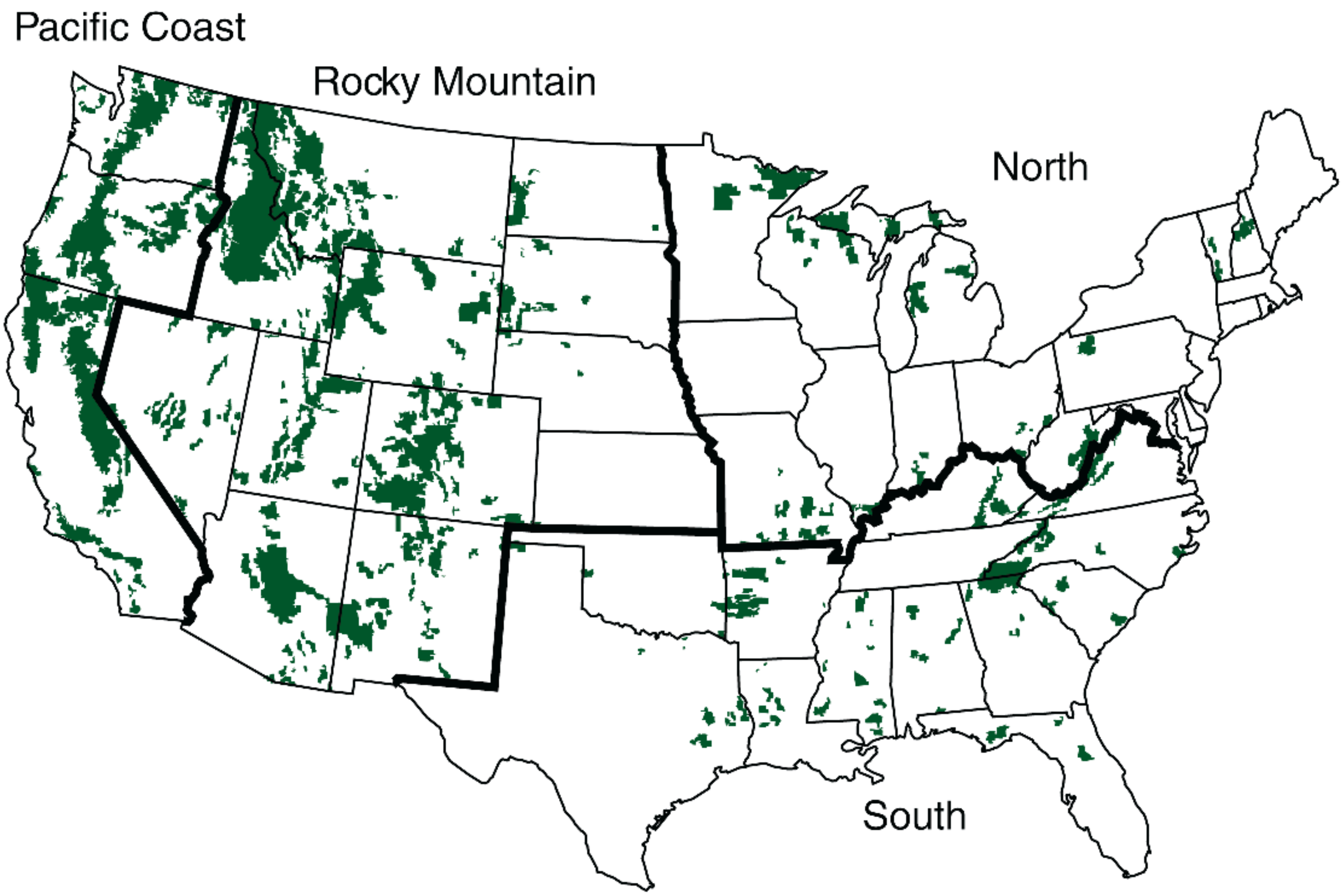



**Fig. 1.5—**USDA Forest Service regions.

# Chapter 2: Extent of Rangelands

## Introduction

Rangeland is a type of land that encompasses a number of major physiographic regions. It is characterized as those areas where the potential natural vegetation is comprised predominantly of grasses, grasslike plants, forbs, and shrubs, and where herbivory is an important ecosystem process (Frank et al. 1998). The Society for Range Management (Glossary Update Task Group 1998) defines rangeland as "land on which the indigenous vegetation is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem." Their definition further states that "rangelands include natural grasslands, savannas, shrublands, many deserts, tundras, alpine communities, marshes and meadows." Rangelands are not limited to those areas grazed by domestic livestock, but include lands suitable only for wild herbivores.

The area of rangeland constitutes a key indicator of conservation and sustainable management at a national scale (Mitchell et al. 1999a). If the term "forest" is replaced by "rangeland" in the Montreal Process criteria and indicators, the following indicators require estimates of the total area of rangeland in relation to classification or land use practices:

*Criterion 1: Conserving biological diversity*

Indicator 1: Extent of area by rangeland type relative to total rangeland area.

Indicator 3: Extent of area by rangeland type in protected area categories.

*Criterion 2: Maintaining the productive capacity of rangeland ecosystems*

Indicator 10: Net area of rangeland available for forage production.

*Criterion 4: Conservation and maintenance of soil and water resources*

Indicator 19: Area of rangeland managed primarily for protective functions.

*Criterion 6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies*

Indicator 35: Area of rangeland managed for general recreation and tourism in relation to the total area of rangeland.

Indicator 42: Area of rangeland managed to protect the range of cultural, social, and spiritual needs and values in relation to the total area of rangeland.

## World's Rangelands

It is not a trivial task to accurately estimate the areal extent of any global land cover type (Bouwman 1990), especially one that crosses biome lines. There is general agreement, however, that rangelands occupy nearly half of the earth's land area or about 65 million $km^2$ (FAO 1990). This total is reached as the sum of permanent pasture, open forest, and half of "other" lands such as desert and tundra (World Resources Institute 1986). The world's rangeland base is roughly broken down as shown in table 2.1. Slightly more than half, or 34 million $km^2$, is used for grazing livestock (Sere and Steinfeld 1996). An additional 3 million $km^2$ of cropland is devoted to cereal production for livestock feed (Steinfeld et al. 1997). *(For comparison purposes, a square kilometer contains 247.1 acres.)*

U.N. Food and Agriculture Organization (FAO) defines four general land-cover categories for global assessments; cropland, pasture, forest, and other. Various authors have compiled estimates of proportional changes in these cover classes (Werger 1983, World Resources Institute 1992). Although total world changes involving pasture land are relatively small, less than 0.1 percent per year, regional shifts are more pronounced (World Resources Institute 1992). Niger, India, and Mongolia are losing pasture land at a much higher rate while South American countries, particularly Brazil, are gaining it (FAO 1987). Rangelands are typically being generated in the tropics as forests are cleared; while in more temperate regions, rangelands are being converted to cropland to satisfy needs of increasing human populations (Graetz 1994).

Current global demographic and environmental trends, however, could cause these slow changes in the rangeland base to become less stable and less predictable (World Resources Institute 1996). The human population

**Table 2.1**—Global extent of major rangeland cover types.

| Land Cover Type | Area ( $10^6$ $km^2$) |
|---|---|
| Grassland | 27 |
| Shrubland | 15 |
| Woodland | 8 |
| Other (tundra, desert, forested) | 15 |
| Total possible rangeland | 65 |

*Grassland, shrubland, woodland estimates from Graetz (1994)*
*Total rangeland estimate from World Resources Institute (1986)*

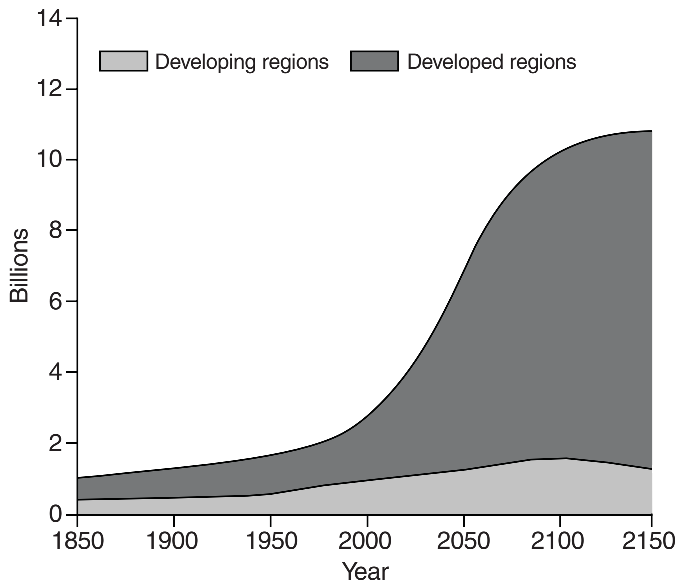



**Fig. 2.1**—Estimated world population growth from 1800 to 2100 AD (adapted from Clarke 1995).

is expected to increase to a range of from 8 billion to 20 billion people by the year 2050 because of the demographic momentum of populations in developing countries with very high proportions in younger age classes (Demeny 1990). The median projection is for a population of about 10 billion people by mid-21st century (Clarke 1995) (figure 2.1). This low median results chiefly from declining fertility rates that overcome continued decreases in mortality (Bongaarts 1998) (table 2.2).

Urban sprawl consumes up to 5,000 km$^2$ of arable land annually in developing countries (U.S. AID 1988). As a consequence, farming operations are systematically displaced onto more marginal lands, including those used for livestock grazing. A Canadian study, described by the World Resources Institute (1996), calculated that replacing the agronomic capability of farmland lost to urban expansion in Ontario required three times as much prairie grazing land to be converted to cropland. Countries with the highest annual increases in urban population tend to be the poorest of countries, mostly located in the tropics, or are wealthy oil states (figure 2.2). Temperate, mid-latitude countries with most of the world's rangelands not only are characterized by annual growth rates of less than 4 percent, but already have significant urban centers to act as the focal point of future expansion (Douglas 1994) (figure 2.2).

One consequence of human population growth will be increasing pressure on basic natural resources, especially water. Since 1940, global withdrawals of fresh water from above-ground and below-ground sources have increased five-fold (Clarke 1993). Many current patterns of water consumption are clearly unsustainable, although in the United

**Table 2.2**—Population estimates in 1995 and projections (billion people) to 2050 by region (from Bongaarts 1998).

| | Year | | |
|---|---|---|---|
| World Region | 1995 | 2025 | 2050 |
| Africa | 0.72 | 1.45 | 2.05 |
| Asia | 3.47 | 4.82 | 5.49 |
| Latin America | 0.48 | 0.69 | 0.81 |
| Europe | 0.73 | 0.70 | 0.64 |
| North America | 0.30 | 0.37 | 0.38 |
| Developing World | 4.52 | 6.82 | 8.20 |
| Developed World | 1.17 | 1.22 | 1.16 |
| World | 5.69 | 8.04 | 9.37 |

States, aggregate withdrawals are expected to be fairly stable because of increased water use efficiency (Brown 1999). The effects of loss of available water to the rangeland base are uncertain: Irrigated farmland could convert to grazing land under some conditions, but semi-arid and arid grazing lands could become unsuitable for livestock production and, to a lesser extent, wildlife if aquifers are depleted to the point where wells and water holes protactedly dry up.

Mismanagement of water has potential to provide credible measures of desertification, discussed below, at a national scale (Sharma 1998). The severity of desertification may be determined from such hydrological indicators as runoff and reduced areas of water bodies.

Also more consequential than actual global rangeland conversion rates are the cumulative losses of soil quality, and hence productivity, because of erosion and desertification (Schlesinger et al. 1990). Soil quality refers to the capacity of a soil to sustain biological productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin 1994). Unfortunately, the extent of erosion and desertification on a world scale is inadequately understood (Graetz 1994). Some in the environmental conservation movement have derived estimates that approach two-thirds of all rangeland (Mabbutt 1984); however, the underlying assumptions are, to a large extent, speculative (Crosson 1995, Pimentel et al. 1995). There is heightened scientific interest in whether some desertification processes may amplify regional climatic changes (Verstraete and Schwartz 1991).

Oldeman et al. (1991) reported upon a UN-sponsored global assessment of human-induced soil degradation. They estimated that 19.6 million km$^2$ of land had been degraded around the world since the end of World War II, 84 percent of it because of wind and water erosion. Of the total land eroded, 37 percent had been lightly eroded, 48 percent had been moderately eroded, 15 percent had been heavily eroded, and 1 percent extremely eroded (table

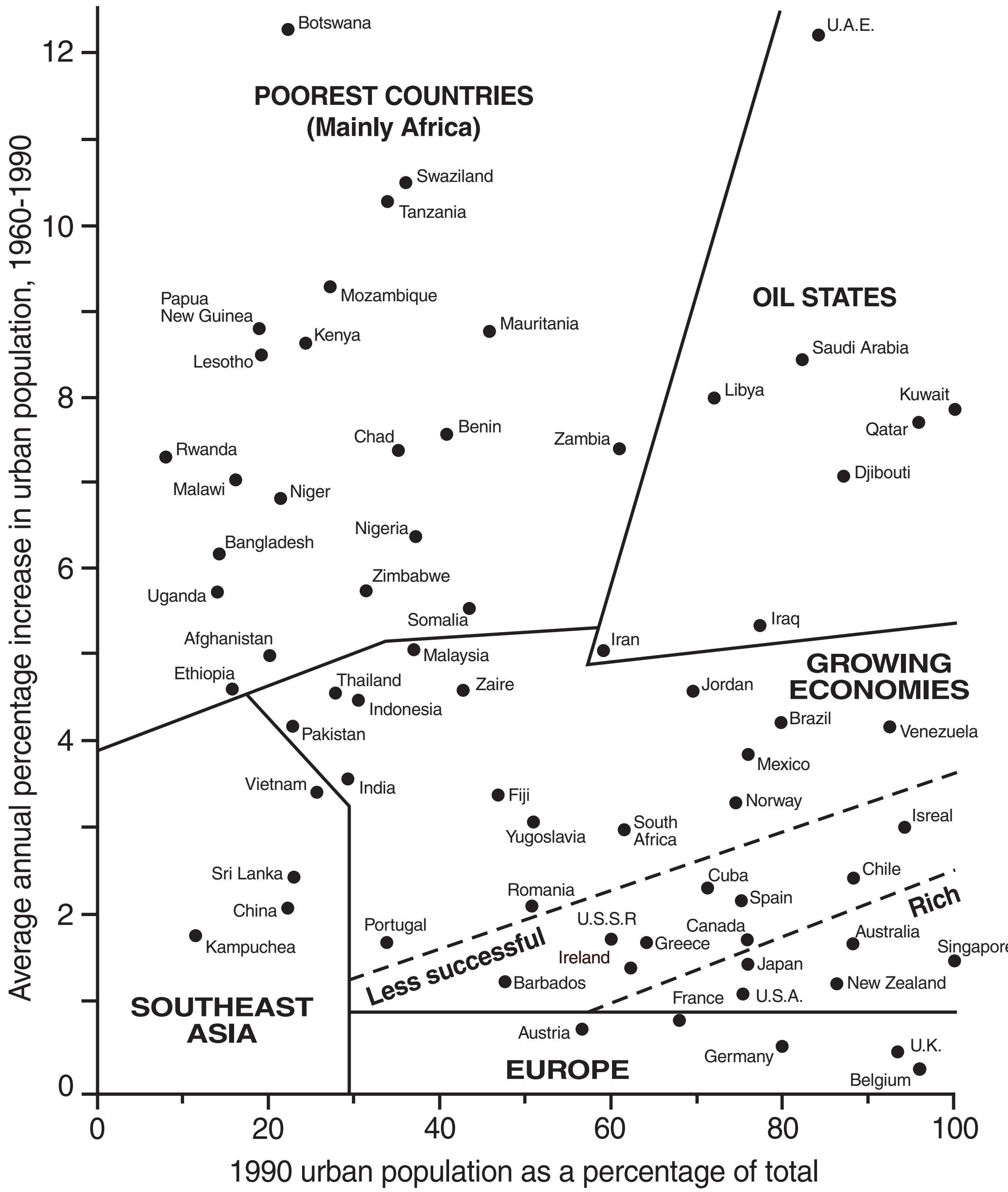



**Fig. 2.2**—Increases in urban populations, by selected countries, in relation to urban proportion of total population (adapted from Douglas 1994).

2.3). The authors did not specify quantitative measures to their ordinal values of degradation, but if the proportions of productivity loss used by Dregne and Chou (1992) are assumed, one can derive an annual rate of productivity loss of approximately 0.5 percent per year since 1945 (Crosson 1995). If true, soil productivity for the earth has declined by 22 percent during the past 50 years.

Nearly all deterioration of soil productivity in the United States is a result of water and wind erosion (figure 2.3). The worst losses are in the Great Plains, with a rough dividing line between water and wind erosion occurring near 100° west longitude. As can be seen in a later section on the Conservation Reserve Program, these highly eroded lands form the core of farmland taken out of crop production and seeded predominantly to perennial grasses to mitigate excessive soil erosion.

The consequences of desertification are cumulative. Oldeman et al. (1991) reported on unpublished comments by E.G. Hallworth in 1988 concerning soil loss from rangelands in Australia. Hallworth observed two "eras" of desertification in the 20th century: the first after sheep and cattle were introduced in large numbers, and the second during the second quarter of the century in association with extensive wind erosion. The land and vegetation became stable again after each era, but species composition had irreversibly changed and primary production may have also suffered. Wang and Hacker (1997) corroborated those observations by showing that severely degraded land in arid zones cannot be restored by optimal grazing management practices, nor even by compete removal of grazing.

Unfortunately, we lack explicit information that can verify the amount of change or degree of instability caused by desertification (Wilson 1989). Existing assessment approaches relied, and largely still rely, upon equilibrium-based models of ecosystem behavior that do not adequately depict non-equilibrium rangeland dynamics (Westoby et al. 1989, Behnke and Scoones 1993).

**Table 2.3**—Global soil degradation by wind and water erosion (ha $10^6$). From Oldeman et al. (1991).

| | Disturbance | | | | |
|---|---|---|---|---|---|
| Country (Land Area) | Light | Moderate | Strong | Extreme | Total |
| North America (1,885) | | | | | |
| Wind | 3 | 31 | 1 | —[1] | 35 |
| Water | 14 | 46 | — | 60 | — |
| South America (1,768) | | | | | |
| Wind | 26 | 16 | — | — | 42 |
| Water | 46 | 65 | 12 | — | 123 |
| Central America (306) | | | | | |
| Wind | 1 | 22 | 23 | — | 46 |
| Water | 1 | 4 | — | — | 5 |
| Africa (2,966) | | | | | |
| Wind | 88 | 89 | 8 | 1 | 186 |
| Water | 58 | 67 | 98 | 4 | 227 |
| Asia (4,256) | | | | | |
| Wind | 132 | 75 | 14 | 1 | 222 |
| Water | 124 | 242 | 73 | — | 441 |
| Europe (950) | | | | | |
| Wind | 3 | 38 | — | 1 | 42 |
| Water | 21 | 81 | 10 | 2 | 114 |
| Australia/New Zealand (882) | | | | | |
| Wind | 16 | — | — | — | 16 |
| Water | 79 | 3 | 1 | — | 83 |
| World (13,013) | | | | | |
| Wind | 268 | 254 | 24 | 2 | 548 |
| Water | 343 | 527 | 217 | 7 | 1,094 |

[1] *Negligible land area.*

Desertification can occur as a consequence of more factors than soil erosion. The National Research Council (Committee on Rangeland Classification 1994) recognized that nutrient cycling could hypothetically be as important to rangeland health as soil stability. Recent work at the Jornada Experimental Range in New Mexico not only has validated such a principle, but presented a conceptual model for linking a transition from desert grassland to shrubs, caused by re-distribution of soil nutrients, to climatic warming. The changes in world climate, in turn, can reinforce the transition process leading to regional desertification (Schlesinger et al. 1990).

If irreversibility and declining productivity are assumed to be essential attributes of desertification, then some of the world's rangelands are in better condition than has been described above. One example is sub-Saharan Africa, where Tucker et al. (1991) showed that the northern boundary had recovered from long droughts over the previous two decades to its historic limits. The authors concluded that rangelands in the Sahel were in a state of dynamic flux rather than in continual decline because of desertification. Milchunas and Lauenroth (1993) analyzed data from more than 200 areas around the world, and found percentage differences in above-ground production between grazed and ungrazed sites to be small where the ecosystem had evolved with grazing, particularly where productivity was low.

This alternative perspective is one of arid and semi-arid rangelands being dynamic and resilient to perturbation when managed by established customs that allow for corrections, both spatially and temporally, during drought (Steinfeld et al. 1997). Under current environmental and social conditions, the essential element seems to be having sufficient time for communities and cultures to react and adapt to non-equilibrium changes (Dunn 1997).

Land ownership reforms constitute a social non-equilibrium change on rangelands, and are serving to intensify rangeland degradation in many developing countries. Government policies pertaining to land ownership rights and restrictions can have a considerable impact on sustainability at a national scale, thus indicators in Criterion 7 of the Montreal Process (Legal, Institutional and Economic Framework for Forest Conservation and Sustainable Management) address the subjects of property rights and land tenure (U.S. Department of Agriculture, Forest Service 1997).

Land transfers became important in the 1960's when the World Bank and some governments began to capitalize livestock development projects (Herlocker 1998). The deleterious effects of privatization and other reforms were not anticipated by those planning and approving these projects; in fact, a number of negative outcomes did not show up until recently. For example, drilling of wells in central Asia led to increasing human populations, rangeland deterioration and, ultimately, decreases in national herd sizes of roughly 60 percent during the last 10 years (Laca and Suleimenov 1998).

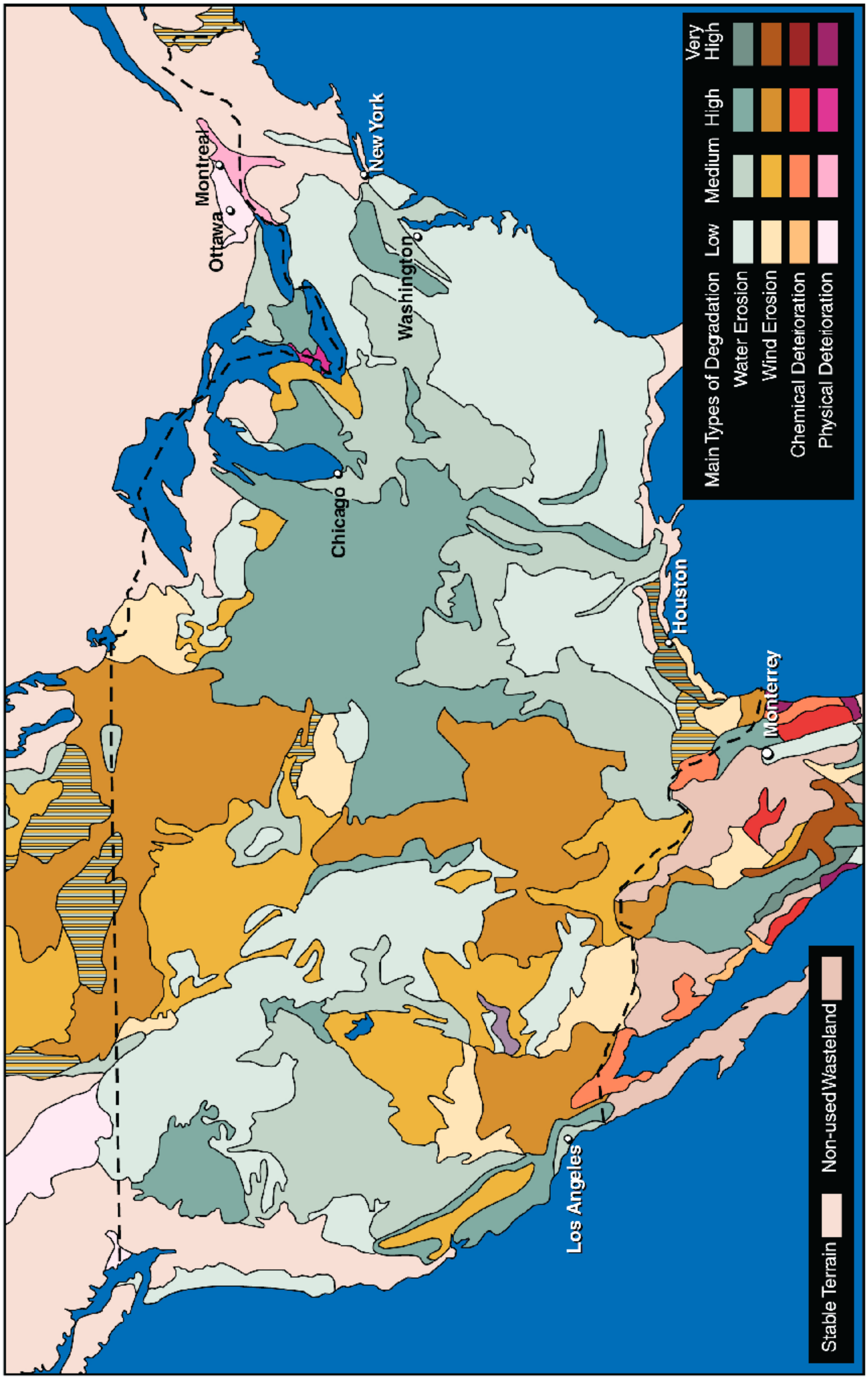



**Fig. 2.3**—Human-induced soil degradation in the United States. (Source: Oldeman et al. 1991).

In Morocco, agricultural commodity and input cost subsidies associated with land reforms led to conversions from rangeland to cereal crop production, which, in turn, accelerated desertification already taking place (Dobrowolski 1998). In Tanzania, the "villagization" process, combined with rapid socio-economic changes caused by population growth, has led to widespread rangeland degradation (East 1998).

Nomadic customs in Tibet, Mongolia, and western China had promoted the maintenance of sustainable rangeland ecosystems for centuries. However, recent state privatization policies have caused graziers to settle in one place. These new practices are starting to transform rangelands on the Tibetan Plateau into less sustainable states (Miller 1998). A comparative examination of land use patterns in Mongolia versus Inner Mongolia (China) and Russian parts of Inner Asia has shown dividing rangeland into individual household pastures greatly reduced large-scale, nomadic pastoral movements. Resulting sedentary grazing systems required large quantities of hay, and the extensive use of heavy machinery to cultivate and store it is causing soil erosion and decreased productivity (Sneath 1998).

In summary, although the status of the world's rangelands outside the United States is little changed since the last Assessment, most evidence points to signs of an accelerating rate of loss in rangeland productivity in developing countries outside the tropics; these losses are caused by increasing pressures from an expanding human population for the basic resources, food and water. These changes may have a limited short-term effect on U.S. rangelands, however, because of a lack of trade in red meat with and decreasing aid to developing countries (Fletcher 1992, Hook 1996).

## U.S. Grazing Lands

Grazing land is any vegetated land that is grazed or that has the potential to be grazed by animals (Glossary Update Task Group 1998). Thus, grazing lands include rangeland, pastures, grazed woodlands, and grazed croplands. Information about the U.S. grazing land base comes from a number of sources. Regrettably, they are neither mutually exclusive nor collectively exhaustive (Zar 1996). The USDA Forest Service, for example, tracks acreages in grazing allotments, land that contains suitable rangeland, unsuitable rangeland, grazed forest land, and ungrazed forest land; however, rangelands not included in allotments are not considered. Therefore, the extent of rangeland must be determined indirectly, based upon more reliable and precise data describing other land categories.

The total land area in the conterminous United States is slightly less than 7.7 million km$^2$ or about 1.9 billion acres. Alaska and Hawaii have another 360 million acres and 4 million acres, respectively. About 29 percent of all U.S. lands, or 660 million acres, is administered by federal civil and defense agencies (USDI Bureau of Land Management 1997a).

Disregarding Alaska and Hawaii, which have little effect on variations in the total U.S. rangeland base, the land used for livestock grazing gradually declined from the end of World War II until the 1980's (USDA Economic Research Service 1997). In 1949, 1.0 billion acres were grazed in the continental United States (Wooten 1953). By 1992, this area had dropped to 801 million acres (Daugherty 1995). Most changes have taken place on private lands because of shifts in land use, including conversion to cropland, urban expansion, improving forage productivity on private lands, and declines in the number of domestic grazing animals (Goddard et al. 1999).

The acreage devoted to grazing in 1992 included the following categories (USDA Economic Research Service 1997):

| | ac. $10^6$ |
|---|---|
| Grassland pasture and rangeland | 589.0 |
| Cropland used for pasture | 66.8 |
| Grazed forestland | 145.0 |

The rangeland/pastures values are slightly less than the rangeland area reported by Joyce (1989). Her estimates were derived from model estimates, however, while the Economic Research Service estimates were based upon various agricultural surveys and the census of agriculture.

The distribution of rangeland in the United States, as described by Joyce (1989), can be described on the basis of Assessment Regions used in the Forest Service's RPA reporting process:

| Assessment Region and States | Percent of Rangeland |
|---|---|
| Pacific Coast: WA, OR, CA | 11 |
| Rocky Mtns: ID, MT, ND, SD, WY, NE, NV, UT, CO, KS, AZ, NM | 69 |
| North: MO and states to N and E | 1 |
| South: VA to OK and south | 19 |

## Non-Federal Grazing Lands

The USDA Natural Resource Conservation Service (NRCS) inventories the Nation's soil, water and related

**Table 2.4—**Areas of non-Federal rangeland and pastureland, by Assessment Region, in relation to the total area of rural land, 1992 (USDA Natural Resource Conservation Service 1995).

| Assessment Region | Acres $10^6$ | | | | |
|---|---|---|---|---|---|
| | Rangeland | Pastureland | Grazed Forestland | Total | Total Rural Land |
| Pacific Coast[1] | 32.9 | 4.5 | 13.7 | 51.1 | 104.0 |
| Rocky Mountains | 253.6 | 15.7 | 19.9 | 282.2 | 453.3 |
| North | .1 | 39.9 | 9.2 | 49.3 | 359.5 |
| South | 112.0 | 65.4 | 20.1 | 197.5 | 468.7 |
| Total | 398.7 | 125.6 | 62.9 | 587.1 | 1,385.5 |

*[1] Includes Hawaii, but not Alaska. The NRI did not sample Alaska until 1997.*
*Note: Grazed forestland sums come directly from the 1992 NRI data base.*

resources found on non-federal lands every 5 years. This National Resources Inventory (NRI) is mandated by Congress (Nusser and Goebel 1997). In 1982, the NRI concentrated on determining the condition of the natural resource base, including rangelands (USDA Soil Conservation Service 1987). The 1992 NRI was designed to appraise changes to the non-federal resource base since 1982 (Nusser et al. 1998).

Privately owned rangeland accounted for 399 million acres of the total U.S. land base in 1992 (USDA Natural Resources Conservation Service 1996). Pastureland and grazed forestland added an additional 126 million acres and 63 million acres, respectively, giving a total non-federal grazing land base in the United States of 587 million acres (table 2.4). This total does not include Alaska or grazed croplands, neither of which are available from the NRI. Alaska was first sampled in 1997.

Non-federal U.S. rangelands, like federal lands, are almost entirely west of the 95° meridian. The North (NO) Assessment Region contains only 130,000 acres of rangeland, all of which is in Missouri. In the South (SO) Assessment Region, nearly all rangeland is in Oklahoma (14 million acres) and Texas (94 million acres). Florida has more than 90 percent of the remaining 3.8 million acres of rangeland in the SO Assessment Region. From a physiographic perspective, Texas and Oklahoma are more similar to the Great Plains states included in the Rocky Mountain (RM) Assessment Region (Bailey 1995).

NRI data indicate the United States lost a net area of 9.3 million acres of grazing land between 1982 and 1992 (Goddard et al. 1999). This is from a 1982 land base of 606.5 million acres of non-federal rangeland, pastureland, and grazed forestland. The net losses and gains by state are shown in table 2.5. Assessment Regions had the following net losses in grazing land between 1982 and 1992:

**Table 2.5—**Net Loss (–) or Gain (+) of Non-Federal U.S. Grazing Lands[1] between 1982 and 1992, by state for those states changing by at least 100,000 acres. From Goddard (In Press).

| State | Acres $10^3$ | State | Acres $10^3$ |
|---|---|---|---|
| SD | –1,429 | IL | –330 |
| TX | –831 | IN | –291 |
| ND | –757 | NY | –284 |
| CA | –669 | WI | –267 |
| FL | –669 | MI | –254 |
| MT | –664 | OH | –185 |
| IA | –611 | ID | –154 |
| CO | –610 | PA | –121 |
| MN | –452 | MS | +500 |
| NE | –442 | KY | +264 |
| KS | –433 | AL | +212 |
| AZ | –382 | GA | +177 |
| NM | –351 | VA | +162 |

*Note: States increasing or decreasing in grazing land less than 100,000 acres are not shown.*
[1] Includes rangeland, pastureland, and grazed forestland.

| Assessment Region | Acres $10^3$ |
|---|---|
| Pacific Coast | 685 |
| Rocky Mountain | 5,400 |
| North | 3,100 |
| South | Not significant |

The SO Assessment Region had no significant reduction in grazing land because five states (MS, KY, AL, GA, and VA) recorded net conversions to grazing land from agricultural uses that totaled more than 1.3 million acres. Together with the other southern states, that was enough to compensate for the large losses of grazing land in Texas and Florida (table 2.5).

The land use to which non-federal grazing land was converted between 1982 and 1992 varied greatly with Assessment Region. Goddard et al. (1999) defined the three categories, developed land, agriculture and miscellaneous as follows:

| Category | NRI Land-Use Classification |
|---|---|
| Developed Land | Large and small urban and built-up, roads and highways, railroads, farm and ranch headquarters |
| Agriculture | Horticulture, row crops, close-grown cropland |
| Miscellaneous | Conservation Reserve Program lands, barren areas, marshland, ungrazed forestland, water |

In this categorization, farmsteads, ranch headquarters, and other rural home sites are included as developed land. Ranchettes and other rural home sites have been reported to be multiplying in several western states since 1990 (Jobes 1993, Riebsame et al. 1996).

Most land coming out of grazing land between 1982 and 1992 in the Pacific Coast (PC) Assessment Region and SO Assessment Region states was converted to developed land. In Texas, more grazing land went into development (1.055 million acres) than was lost, on a net basis, from the grazing land base. This could happen because Texas recorded a net increase in grazing land from agricultural land during the same time period (table 2.5). States in the SO Assessment Region that had a net gain in grazing land also lost land to development, but those conversions were more than offset by shifts from agricultural uses to grazing.

States in the RM Assessment Region primarily lost grazing land to agricultural uses (table 2.5). Plowing of rangeland for wheat and other close-grown crops was a recognized influence on the Great Plains during the 1980's. Laycock (1988) estimated that at least 4.5 million acres of native grassland was plowed in the Northern and Central Great Plains, alone. The causal factor was a large shortfall in world grain production in 1972 that induced the U.S.S.R. to purchase more than 700 million bushels of grain from the United States, including 25 percent of the total U.S. wheat crop (Sobel 1975). This and other sales, coupled with continued high demand, drove the price of wheat from $1.32 per bushel in July 1972 to a new high of $5.93 per bushel the following year. Prices for grains had weakened by 1987, but by then the fraction of farmland in crops stood at 41 percent, an all-time high (Crosson 1991). Plowing of rangeland may have lagged behind the outset of high wheat prices because many Great Plains farmers first increased production by expanding onto idle lands (Crosson 1991). For example, the amount of land farmers were required to leave idle under provisions of the federal feed support program was reduced from 25 percent to 10 percent in 1973 (Sobel 1975).

The NO Assessment Region, as noted above, has no significant rangeland. Accordingly, all net losses of grazing land came from pastureland and grazed forestland. Only one state in this assessment region, Iowa, lost more than a half-million acres. Another eight states lost between 100,000 acres and 500,000 acres (table 2.5).

## Non-Federal Rangeland

Nearly 8.6 million acres of non-federal rangeland was converted on a net basis to other uses between 1982 and 1992 (Goddard et al. 1999). The decline amounted to roughly 2 percent of the 1982 non-federal rangeland base of 409 million acres (USDA Natural Resources Conservation Service 1995). No states gained rangeland, although it should be noted that lands put into the Conservation Reserve Program under provisions of Title XII of the 1985 Farm Bill were not categorized as rangeland in this report. The net losses by state are shown in table 2.6. Assessment Regions had the following net losses between 1982 and 1992:

| Assessment Region | Acres $10^3$ |
|---|---|
| Pacific Coast | Not significant |
| Rocky Mountain | 5,100 |
| North | Not significant |
| South | 3,100 |

The NO Assessment Region contains by far the lowest amount of rangeland, only 130,000 acres (table 2.4). As a result, it is extremely difficult to detect even substantial changes for this region because of the low sampling population in relation to the NRI grid.

As for all grazing lands, the land use to which non-federal rangeland was converted on a net basis differed by Assessment Region. In the PC Assessment Region, about half of all rangeland was changed to agricultural lands with lesser amounts going to the miscellaneous and developed land categories. Rangeland changing use in the SO Assessment Region tended to be divided equally among developed land, agricultural land, and the miscellaneous category (table 2.6).

In the RM Assessment Region, which contains the most rangeland (table 2.4), net losses were dominantly shifted into agriculture to even a greater extent than for all grazing lands (table 2.6). The one outlier seems to be in New Mexico where for some reason the majority of its rangeland was transferred to the miscellaneous category. The likely reason for such a categorical conversion is the same

**Table 2.6—**Net conversion of non-Federal U.S. rangeland to development, agricultural and miscellaneous uses between 1982 and 1992 for those states changing by at least 100,000 acres. From Goddard et al. (1999).

| Assessment Region/State | Change in rangeland (acres 10³) | Percent Converted to | | |
|---|---|---|---|---|
| | | Developed Land | Agriculture[1] | Miscellaneous[2] |
| Pacific Coast | | | | |
| WA | 166 | 20 | 49 | 31 |
| Rocky Mountains | | | | |
| MT | 977 | 03 | 89 | 08 |
| SD | 824 | 02 | 91 | 07 |
| KS | 655 | 06 | 68 | 26 |
| ND | 635 | 06 | 79 | 15 |
| NM | 477 | 23 | 16 | 61 |
| NE | 419 | 05 | 75 | 20 |
| CO | 390 | 34 | 78 | –12[3] |
| South | | | | |
| TX | 1,181 | 55 | 16 | 29 |
| OK | 1,002 | 07 | 38 | 55 |
| FL | 877 | 30 | 43 | 27 |

[1] *Includes pastureland.*

[2] *Includes grazed forest land and CRP land considered rangeland in the 1992 NRI.*

[3] *Negative percentage indicates transfer of land use into grazing.*

as for all grazing lands in the RM Assessment Region: high demand for wheat and other grain crops.

## The Conservation Reserve Program

The last rangeland assessment (Joyce 1989) described agricultural policy and conditions that led to conservation provisions in the Food Security Act of 1985 (1985 Farm Bill). One of these provisions, The Conservation Reserve Program (CRP), has had a major influence on land cover in the United States (Mitchell 1988, Joyce et al. 1991). The CRP is a voluntary cropland retirement program that provides farm owners, operators, or tenants with an annual rental payment, plus an establishment cost-share, for establishing a permanent cover of grass, wildlife habitat, or trees. CRP was created to retire highly erodible or environmentally sensitive cropland from crop production for a period of 10 to 15 years.

The Food, Agriculture, Conservation, and Trade Act of 1990 extended the CRP and broadened its objective to include improving water quality and other environmental goals. In 1996, The Federal Agriculture Improvement and Reform Act amended the 1985 Farm Bill and confirmed CRP's new focus.

An enrollment goal of at least 40 million acres was set by the 1985 Farm Bill. By the end of the 1989 crop year (9th signup) 29.8 million acres had been accepted into the program. This rapid expansion over a three-year period had several negative effects: A depletion of the native plant seed supply, leading to substitution of lower quality native and non-native species in many plantings; dramatic downturns for agricultural businesses in some areas that affected the well-being of local communities; and inadequate time for planning (Laycock 1991).

By 1993, and 12 signups after being implemented, 36.4 million acres had been enrolled in the CRP (figure 2.4). The annual total rental payment at that time amounted to $1.8 billion (USDA Farm Services Agency, unpublished report). Forty-five percent of this land area was in the RM Assessment Region. Both the NO and SO Assessment Regions had about one-quarter of CRP lands, with the remaining 5 percent situated in the PC Assessment Region. However, Oklahoma and Texas had more than 5.3 million acres of the South's total. If these Great Plains states were added to the RM Assessment Region, the latter's land in CRP would have amounted to 21.7 million acres, or 60 percent of all land enrolled through the 12th signup period (table 2.7). Much of the CRP lands in the SO Assessment Region outside of Texas and Oklahoma were planted to trees, signifying their importance as forestland rather than rangeland.

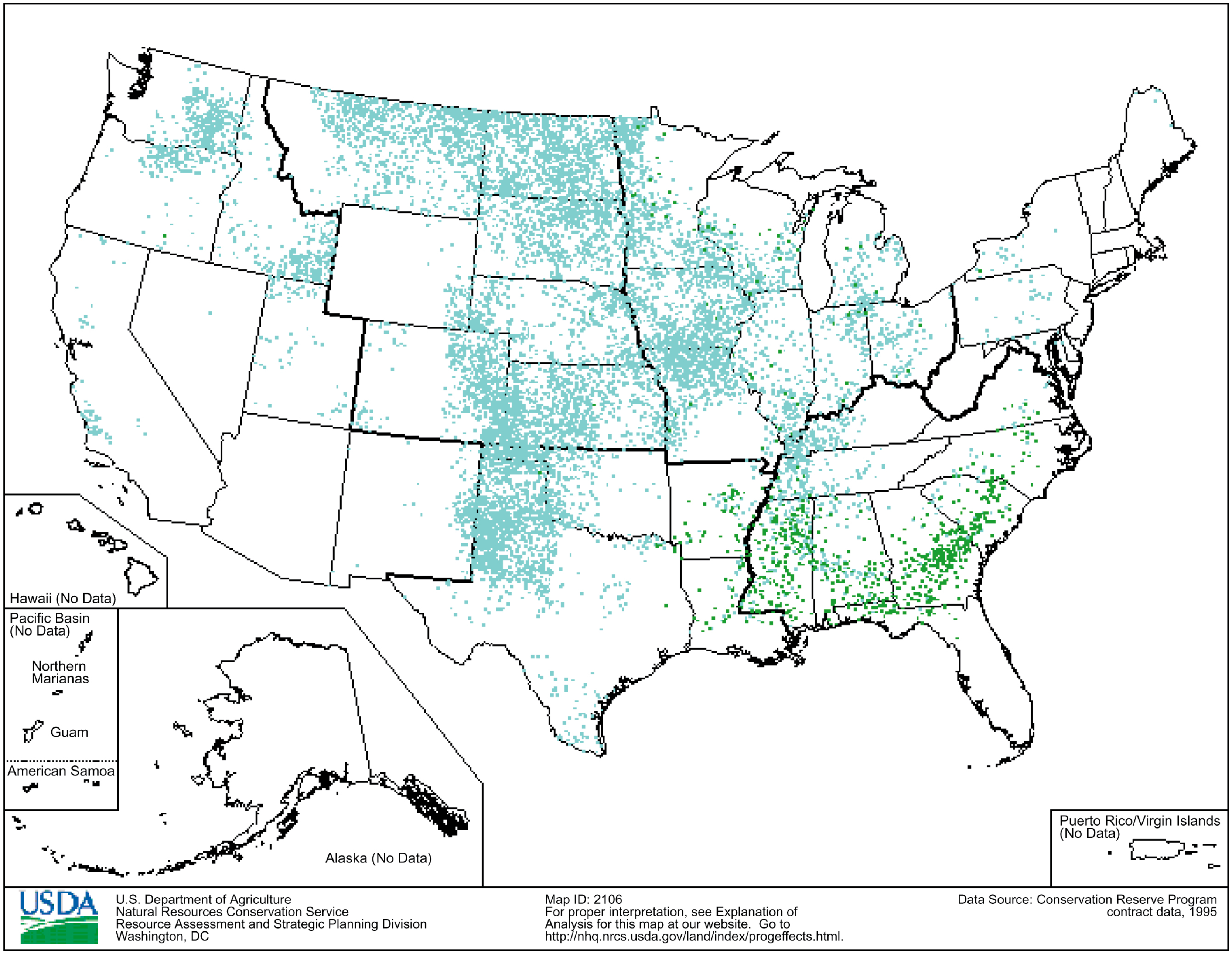



**Fig. 2.4**—Distribution of CRP land in the United States through the 12th signup, 1993. Each blue dot represents 3,000 acres planted to other than trees (primarily grass), and each green dot represents 3,000 acres planted to trees. (Source: USDA Natural Resources Conservation Service, contract data, 1995).

**Table 2.7—**Land area enrolled in the Conservation Reserve Program through the 12th signup period, 1993, by Assessment Region and state. Area in acres $10^3$.

| Pacific Coast | Area | Rocky Mtn | Area | South | Area | North | Area |
|---|---|---|---|---|---|---|---|
| CA | 187 | CO | 1,978 | AL | 573 | DE | 1 |
| OR | 531 | ID | 877 | AR | 260 | IL | 812 |
| WA | 1,047 | KS | 2,938 | FL | 135 | IN | 463 |
| Total | 1,765 | MT | 2,854 | GA | 706 | IA | 2,225 |
| | | NE | 1,425 | KY | 451 | MD | 20 |
| | | NV | 3 | LA | 147 | ME | 38 |
| | | NM | 483 | MS | 842 | MI | 333 |
| | | ND | 3,181 | NC | 151 | MN | 1,929 |
| | | SD | 2,120 | OK | 1,193 | MO | 1,727 |
| | | UT | 234 | SC | 278 | NY | 64 |
| | | WY | 257 | TN | 476 | OH | 377 |
| | | Total | 16,350 | TX | 4,150 | PA | 101 |
| | | | | VA | 80 | WI | 746 |
| | | | | Total | 9,442 | Total | 8,836 |

In late 1994, USDA decided to allow CRP participants to release their contracted land before the contract expiration date without penalty, with certain exceptions tied to parcels adjoining streams or other water bodies.

Starting with the 13th signup, CRP contracts were designed to put greater emphasis on improving water quality and wildlife habitat. Bids were ranked using an environmental benefits index that gives preference to lands that are considered highly erodible, cropped wetlands, lands subject to scour erosion, and/or lands in national or state CRP priority areas. Overall, however, the amount of land under CRP contract declined to 33.0 million acres by the end of 1996 and will have fallen to slightly more to 31.3 million acres in October 1999 (Unpublished USDA press release). The 1996 Farm Bill limits the amount of land enrolled in CRP to 36.4 million acres, the land area under contract after the 12th signup.

Because of the priorities contained in the "new" CRP, distribution of enrolled lands has changed during the signups since 1996. A greater proportion of the contracts are being approved in areas affected by water erosion more than wind erosion which, in the Great Plains, is shifting the locus of points eastward (figure 2.5).

Much of the lands placed in the CRP have been planted to native rangeland species. However, they cannot be grazed by domestic livestock or hayed except during certified emergencies such as droughts. Thus, these lands are not regarded as rangeland for classification purposes by the NRCS. Difficulties in converting former cropland fields to livestock production systems provide another reason for putting CRP lands in the miscellaneous category. For example, perimeter and interior fencing must be constructed, water developed, corrals and other livestock handling facilities built, and livestock purchased (Dodson and McElroy 1995).

Most economic data and landowner preference information indicate that farmers favoring retention of land under permanent cover do not have much land under CRP contract (Heimlich and Kula 1991). The area of CRP land ultimately converting to rangeland after all CRP contracts terminate will depend upon the long-term relative economics of crop and livestock production, including agricultural policy, and the kinds of values held by CRP participants (Heimlich 1995).

No published research forecasts a significant long-term increase in rangelands for livestock grazing because of the CRP. A comprehensive 1993 survey of CRP participants conducted by the Soil and Water Conservation Society concluded that 37 percent of land at the time would not be returned to crop production after the contracts expired, assuming that crop prices remained at 1993 levels. The survey also indicated that approximately 8.3 million acres enrolled in the CRP in 1993 would be used for pasture or grazing by cattle if contracts were not renewed (USDA Economic Research Service 1994).

Another study, using data from the 1993 survey, raised doubts that so much land would be grazed (Dodson and McElroy 1995). The study noted, using state average stocking rates, that only 21 percent of enrollees would have sufficient CRP land to stock 50 or more animal units on this land. Moreover, less than 40 percent of farms in the CRP reported having other pasture or cattle (only 14 percent had more than 100 head of cattle), suggesting that a large majority of CRP contract holders lack both the expertise and equipment to handle livestock. Farmers who do have the capacity to expand livestock opera-

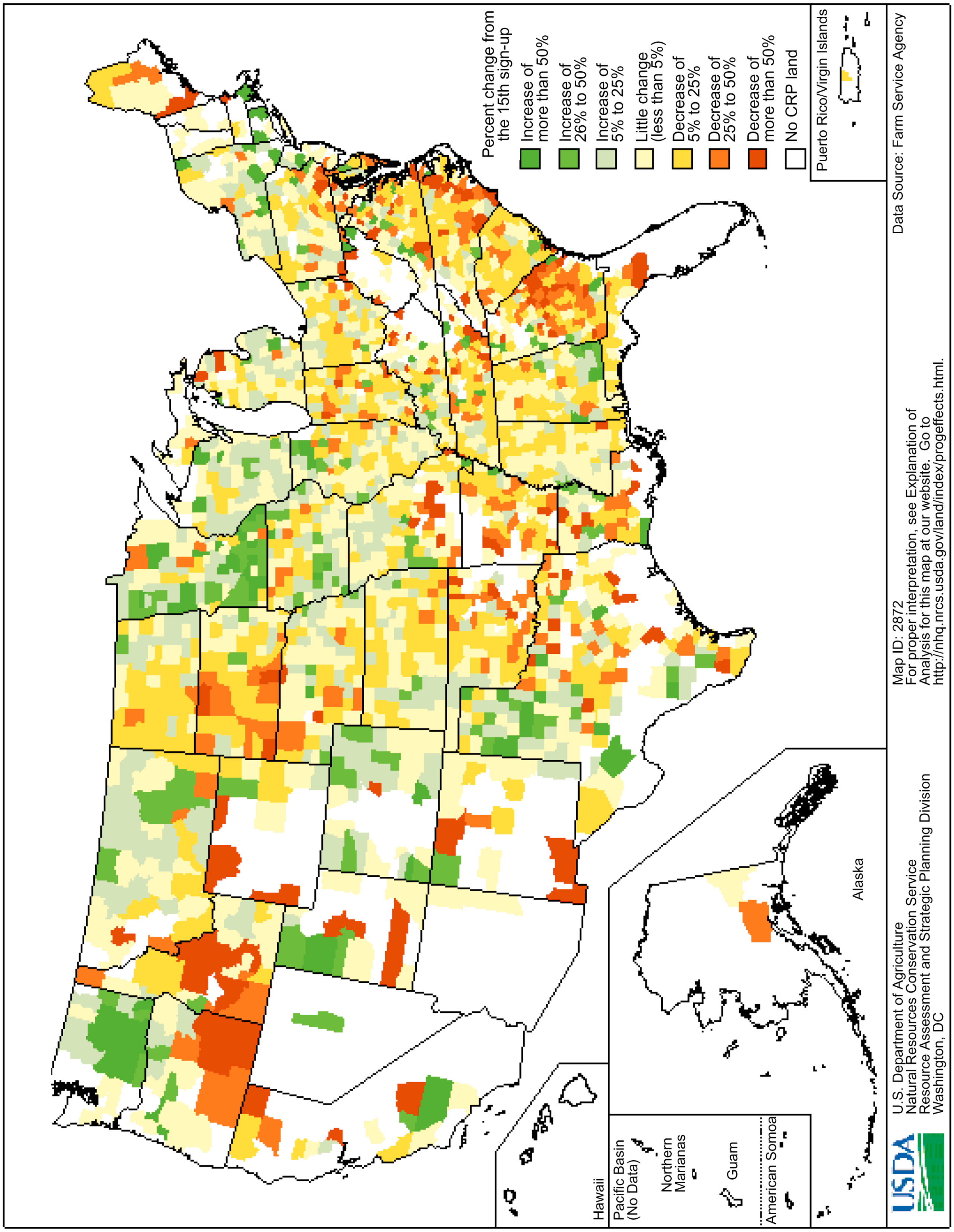



**Fig. 2.5**—Distribution of percent change in Conservation Reserve Program lands from the 15th signup in March 1997 to the 16th signup in October–November 1997. (Source: USDA Natural Resources Conservation Service, contract data, 1995).

tions tend to be concentrated in the Central and Northern Great Plains (Dodson and McElroy 1995).

Research has demonstrated the effectiveness of CRP lands in enhancing wildlife habitat, especially for some ground nesting birds (Herkert 1998, Brady and Flather 1998). Consequently, areas having economic incentives for wildlife habitat, such as in the Northern Great Plains, may primarily determine where CRP lands will be permanently converted to rangeland (Johnson and Schwartz 1993).

A principal social intent for maintaining erodible farmland in a conservation program is to decrease soil erosion. According to USDA Natural Resources Conservation Service data, annual reductions in topsoil loss for land within the CRP amounted to 700 million tons by 1993, or an average of 19 tons per acre (USDA Economic Research Service 1994). Two far-reaching unknowns will impact the future of CRP lands: (1) Whether the federal government will indefinitely continue to fund a conservation program involving annual outlays of approximately $200 million for the public good of decreased soil erosion; and (2) if not, whether significant numbers of contract holders in areas not having high wildlife values will opt to keep their land under permanent cover with decreased or no monetary remuneration for doing so.

## National Forest System Lands

The extent of rangelands on National Forest System (NFS) lands is difficult to ascertain. The 1989 Assessment estimated the total to be 40.66 million acres. This broke down by Assessment Region to (USDA Forest Service 1989):

| Assessment Region | Rangeland Area (Acres $10^3$) |
|---|---|
| Pacific Coast | 10,813 |
| Rocky Mountain | 29,785 |
| South | None |
| North | 65 |

Forest Service estimates of NFS rangeland are presently defined on a different basis, making any comparisons with the 1989 data infeasible. They are enumerated as the area of land with range vegetation, either upland or riparian, within grazing allotments having range vegetation management objectives. The Range Management Staff, Washington Office, USDA Forest Service approximated the following extent of such lands, by Assessment Area, for 1997:

| Assessment Region | Upland Rangeland Area (Acres $10^3$) | Riparian Rangeland Area (Acres $10^3$) |
|---|---|---|
| Pacific Coast | 17,349 | 785 |
| Rocky Mountain | 53,763 | 1,576 |
| South | 1,169 | 60 |
| North | 65 | <1 |
| All NFS Lands | 72,346 | 2,421 |

The discrepancy between the 1997 estimates and those contained in the 1989 RPA Assessment is primarily attributed to differences in the way individual national forests determined rangeland area in 1997. Some Forests, for example, included all lands within the borders of range allotments, regardless of whether they were unsuitable for grazing because of timber cover (Personal communication, Rita Beard, Range Management Staff, Washington Office, USDA Forest Service). Thus, it is likely that the extent of rangelands on NFS lands is not significantly different from what was reported in 1989 (USDA Forest Service 1989). National Resources Inventory data disclose that all federal lands together increased by only 3.29 million acres, or 0.5 percent of the federal land base, between 1982 and 1992 (USDA Natural Resources Conservation Service 1995). Therefore, NFS lands, including rangelands, have not increased significantly during the past 20 years.

## Rangelands Managed by the Bureau of Land Management

The Bureau of Land Management (BLM) has jurisdiction over 137 million acres within grazing districts, including Land Utilization Project lands transferred to the Department of Interior from the Department of Agriculture by various executive orders. It is responsible for an additional 108 million acres of public land that are not included in grazing districts, 87 million acres of which are located in Alaska, along with 19 million acres of other reserved land (USDI Bureau of Land Management 1997b).

Lands within grazing districts are managed according to the Taylor Grazing Act of 1934, as modified by the Federal Land Policy and Management Act of 1976 (FLPMA). Lands outside of grazing districts are managed solely under FLPMA, which gave BLM a unified legislative

**Table 2.8—**Area of public lands under the management of USDI Bureau of Land Management for the Pacific Coast and Rocky Mountains Assessment Regions, 1996. Area in acres $10^3$.

| Pacific Coast | | | Rocky Mountains | | |
|---|---|---|---|---|---|
| State | Grazing Districts | Other Public Lands | State | Grazing Districts | Other Public Lands |
| CA | 1,725 | 7,380 | AZ | 10,093 | 1,517 |
| OR | 12,459 | 578 | CO | 6,776 | 480 |
| WA | None | 362 | ID | 10,737 | 423 |
| Total | 14,184 | 8,320 | MT | 4,940 | 1,151 |
| | | | NE | None | 7 |
| | | | NV | 44,493 | 3,137 |
| | | | NM | 11,113 | 1,356 |
| | | | ND | None | 59 |
| | | | SD | None | 272 |
| | | | UT | 21,159 | None |
| | | | WY | 11,274 | 3,916 |
| | | | Total | 120,585 | 12,318 |

mandate to manage all public lands—lands that were to "be retained in Federal ownership." There are minor differences between how the two categories of land are managed; for example, grazing permits are awarded on rangelands within grazing districts, while leases are allowed on rangelands outside of grazing districts. Nonetheless, there is little difference between how permits and leases are administered.

Nearly all BLM public lands not classified as reserved, both those within grazing districts and those without, are deemed to be rangeland (Personal communication, Thomas C. Roberts, Jr., Washington Office Range Management Staff, USDI Bureau of Land Management). Public lands outside of Alaska sum to 155.4 million acres (table 2.8), or 6.6 million acres more than was attributed to BLM rangelands in the 1989 RPA land base assessment document (USDA Forest Service 1989). Assuming the accuracy of the 1989 estimate, that means more than 95 percent of BLM public lands are classified as rangeland.

Essentially all BLM rangelands are found in the PC and RM Assessment Regions. Public lands outside of grazing districts are limited to 16,000 acres in seven states in the SO Assessment Region and less than 9,000 acres in two states, Minnesota and Wisconsin, in the NO Assessment Region. About three-fourths of all BLM lands can be found in the Intermountain region of the western and southwestern United States (table 2.8).

The extent of rangeland under BLM control is stable and is expected to be so in the future. Between 1986 and 1996, the amount of land within grazing districts diminished by 1.5 percent from 136.8 million acres to 134.8 million acres. Concomitantly, the land area outside of grazing districts, excluding Alaska, decreased from 26.1 million acres to 20.7 million acres, primarily because of large transfers totaling 5.4 million acres in California, including the 1.6 million acre Mojave National Preserve created by the 1994 California Desert Protection Act.

## Outlook for the U.S. Rangeland Base

Two antithetical processes, consolidation and subdivision, are influencing the nature of the U.S. rangeland base, and nothing shows on the horizon that can be expected to significantly alter this pattern over the next 50 years.

Consolidation is the process of concentrating private rangeland among fewer and fewer holders. Today, less than 2 percent of farmland owners possess more than one-third of U.S. farmland (USDA Economic Research Service 1994). Between 1988 and 1997 the number of farms in the United States decreased from 2.20 million to 2.06 million, while the average farm size increased from 452 acres to 471 acres (USDA National Agricultural Statistics Service 1998). Since the mid-1930's the decline in farm numbers has approximated an inverse exponential curve, meaning that the rate of decrease will presumably lessen in future years (figure 2.6).

Farms and ranches are subdivided into smaller units for multiple reasons, but primarily to allow children of farmers to have their own land or to raise capital to pay debt. Farmland subdivided for economic purposes may or may not remain in that use.

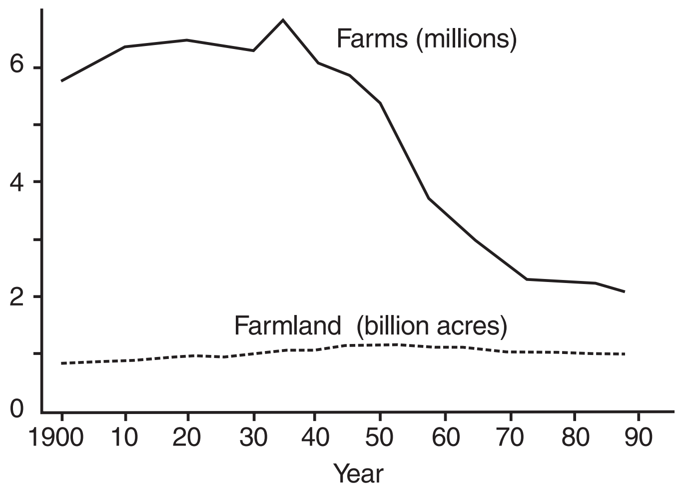



**Fig. 2.6—**Trends in the number of U.S. farms and amount of farmland between 1900 and 1990. A farm is any establishment from which $1,000 or more of agricultural products, including livestock, are sold or normally would be sold during a given year, and farmland is all land used to produce those agricultural products.

In some scenic parts of the rangeland West, pastureland and rangeland value is appreciating so rapidly that ranchers have come under extreme economic pressure to subdivide their lands for rural homes or "ranchettes." Such appreciation has been fueled by a significant immigration into the mountain states of the RM Assessment Region since 1990, resulting in part from an expanding high-tech, professional service industry that is not physically tied to metropolitan centers (Riebsame et al. 1997). The five most rapidly growing states between 1990 and 1994 were from this region (table 2.9). Ranchettes are commonly developed in parcels of 35 acres or slightly larger, sometimes to circumvent local and county zoning regulations. In semi-arid foothill locations, 35 acres are often inadequate for commercially raising livestock, yet constitute too large a block of land to be recognized as being a built-up landscape by the NRI or remotely sensed classification systems. Thus, the extent of subdivisions for rural homes is mostly undetermined. The spatial distribution of successful and unsuccessful developments for rural homes across all grazing lands also has not been described.

Both consolidation and subdivision can be seen by examining the changing distribution of number of farms and ranches by farm economic sales class over time. For example, smaller working farms and ranches in the 13 western states (where most rangelands occur), including Alaska and Hawaii, decreased while those making less than $10,000 or more than $100,000 increased between 1995 and 1997 (table 2.10). The increasing number of small "hobby" farms that have farm-related incomes between $1,000 and $10,000 is probably causing the rate of farm decline shown in figure 2.6 to be flatter than a true negative exponential curve.

To summarize, the amount of grazing land and rangeland in the United States is expected to continue slowly declining over the next 50 years. However, land use shifts away from grazing use will be much greater in areas of more rapid population increases and concomitant appreciation in land values. Whether states in the Rocky Mountains and their foothills will continue to dominate locations of high immigration by the year 2050 is unknown. Research supporting the forage demand projections, however, suggests that changes in land use will decrease the amount of land available for grazing to a greater extent in a consolidated PC and RM Assessment Region than either the NO or SO Assessment Regions throughout the foreseeable future (Van Tassell et al. 1999).

**Table 2.9—**States with the greatest population growth rate during the period 1990 to 1994. From Riebsame et al. (1997).

| State | Population growth (Percent) |
|---|---|
| 1. Nevada | 21.2 |
| 2. Idaho | 12.5 |
| 3. Arizona | 11.2 |
| 4. Colorado | 11.0 |
| 5. Utah | 10.7 |
| 6. Alaska | 10.2 |
| 7. Washington | 9.8 |
| 8. New Mexico | 9.1 |

**Table 2.10—**Change in economic sales class of farms and ranches in the 11 western states[1] (where most rangelands occur) plus Alaska and Hawaii between 1995 and 1997. From USDA National Agricultural Statistics Service (1998).

| | Economic sales class Number of farms $10^3$ | | | |
|---|---|---|---|---|
| Year | <$10,000 | $10,000–99,999 | ≥$100,000 | Total |
| 1995 | 126.6 | 100.0 | 47.7 | 274.3 |
| 1996 | 130.7 | 96.2 | 50.2 | 277.1 |
| 1997 | 135.1 | 92.1 | 51.9 | 279.1 |

[1] *AZ, CA, CO, ID, MT, NV, NM, OR, UT, WA, WY*

# Chapter 3: Rangeland Health

## Introduction

Indicators of rangeland health vary between those applying to national-level criteria and those that apply to management-unit or site-specific criteria. Classical conventions for assessing rangeland health have dealt exclusively with the latter. In fact, at least two indicators of range condition at a site level are manifested in criteria other than ecosystem health and vitality (Criterion 3) of the Montreal Process (U.S. Department of Agriculture, Forest Service 1997): The extent of area by successional stage appears in Criterion 1, conserving biodiversity (Flather and Sieg 2000), and area with significant soil erosion appears in Criterion 4, conservation and maintenance of soil and water resources (Neary et al. 2000). This chapter deals primarily with local measures of rangeland condition, although the chapter summary attempts to synthesize them into a national-level assessment of rangeland health.

The decade since the last technical document supporting the RPA Assessment (Joyce 1989) has seen rapid advances in how rangelands have been viewed from a condition or health context. Early management concepts of range condition (Dyksterhuis 1949) were based upon the Clementsian equilibrium theory of retrogression caused by overgrazing, and by secondary succession to a stable climax following removal of the grazing disturbance. Although the Forest Service had incorporated soil condition (erosion and erodibility) into its protocol for assessing range condition by the early 1950's (Ellison et al. 1951), vegetation condition continued to be differentiated following the Clementsian model (Parker 1954).

The abstraction of four range condition classes (excellent, good, fair, poor) remained ingrained into inventory and assessment processes of U.S. land management agencies (DeGarmo 1992), even after scientific evidence began challenging the Clementsian vision of succession (Slayter 1975, Wilson and Tupper 1982, Archer 1989). Consequently, the last RPA technical document was obliged to report rangeland health in these terms for all agencies (Joyce 1989).

The seminal alternative hypothesis for non-equilibrium vegetation dynamics on disturbed rangelands was advanced by Westoby et al. (1989). At the same time, ecologists in various disciplines began to question whether ecosystem behavior under stress should be described only on the basis of vegetation responses (Rapport et al. 1985). The manner in which the range condition concept evolved from a simplistic, universally accepted model to the present changing, complex situation has been described by Joyce (1993).

In 1989, the Board on Agriculture of the U.S. National Research Council convened a Committee on Rangeland Classification to examine the scientific basis of methods used by the USDA Forest Service, USDA Natural Resources Conservation Service (NRCS) (then, called Soil Conservation Service), and the USDI Bureau of Land Management (BLM) to classify, inventory, and monitor rangelands. The Committee fulfilled its assignment through meetings, field investigations, and interviews. Their report was issued as a book in 1994 (Committee on Rangeland Classification 1994). The report proposed a new paradigm for assessing rangeland health—one based upon non-equilibrium, state-and-transition models of succession that focus on ecosystem function rather than ecosystem state (plant community composition). Three major criteria suggested were soil stability and watershed function, distribution of nutrient cycling and energy flow, and recovery mechanisms.

At about the same time, the Society for Range Management assembled a Task Group on Unity in Concepts and Terminology to seek agency commonality in technology and methodology relating to rangeland condition and trend. The Task Group report called for making sustainability the fundamental goal of rangeland management (Task Group on Unity in Concepts and Terminology 1995). They defined sustainability in terms of maintaining soil productivity. Therefore, the primary goal of management would be to keep wind and water erosion to a rate below that where soil loss reduces the productive potential for a site.

Unfortunately, the scientific advances described above have not yet been incorporated into national data sets of rangeland condition. The Western Regional Research Coordinating Committee on Rangeland Research concluded that thresholds for sustainability can only be determined through monitoring benchmarks representing well-managed ecological sites in arid and semi-arid areas (West et al. 1994). Relict areas can be situated in topographic features that isolate them from different disturbance patterns than the surrounding landscape, especially with reference to wildlife grazing and fire (West 1991a).

Nor are data sets of rangeland condition standardized in a manner that allow comparisons among federal agencies. This chapter will assess condition as reported by the NRCS for non-federal rangelands and by the Forest Service and BLM for federal lands under their jurisdiction. In 1997, these three primary land management agencies entered into a memorandum of understanding to establish a Federal Interagency Rangeland Health Committee to standardize the methodology for inventorying, monitoring, and assessing the status of rangeland health on all U.S. lands. Thus, future range assessments should have more opportunity to describe the rangeland health situation at the management unit level in a coordinated and consistent way.

Two factors relating to trees have affected rangeland condition during the 20th Century. They are encroachment of brush and woodlands onto grasslands, and the decline of quaking aspen (*Populus tremuloides*) (Bartos and Campbell 1998). Both are seen as rangeland sustainability issues and are discussed in this chapter.

Finally, the spread of non-indigenous plants onto U.S. rangelands has had a considerable deleterious effect on sustainability (U.S. Congress, Office of Technology Assessment 1993). The area of forest (or rangeland) affected by processes or agents beyond the range of historic variation, including exotic species, is an indicator of ecosystem health in the Montreal Process, so trends of unwanted non-indigenous rangeland plants are also examined separately.

# Condition of Non-Federal Rangelands

Condition of non-federal rangelands was reported in the 1989 Assessment (Joyce 1989) from data collected during the 1982 National Resource Inventory (NRI) (USDA Soil Conservation Service 1990). The NRI was directed by the 1972 Rural Development Act to provide Congress with current information concerning the status and trends of soil, water, and related resources on non-federal lands. The NRI is repeated every five years using a stratified, two-stage random area sample of primary sampling units (PSU). By 1982, more than 300,000 PSU's had been established. The second sampling stage consists of three or less permanent sample points situated within each PSU according to a restricted sampling process (Nusser and Goebel 1997).

In 1992, a study supplementing the 1992 NRI was conducted to estimate range condition and trend, as well as other indicators of rangeland health, in the 17 conterminous western states plus Florida and Hawaii. The supplemental study obtained data from field sampling techniques that followed nearly the same procedures for estimating condition and apparent trend as was carried out in the 1982 NRI. The results of the supplemental study, which were not included in the 1992 NRI (USDA Natural Resources Conservation Service 1995), have not been published. Those results can still be used, however, to crudely assess rangeland health over the 10 years between these two sampling periods by comparing state range condition summaries with those in the 1982 NRI.

Both the 1982 NRI and 1992 supplemental study evaluated range condition on the basis of species composition following the Dyksterhuis (1949) model. Species composition, estimated on a biomass basis, is compared to a typical "climax" plant community for the range site being rated. A range site, now called an ecological site, is defined as "a kind of land with specific physical characteristics which differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its response to management" (Task Group on Unity in Concepts and Terminology 1995).

## Pacific Coast Region

It is infeasible to estimate trend in rangeland condition for the entire Pacific Coast (PC) Assessment Region because data were not obtained in California during 1992. Of the 17 million acres of non-federal rangeland in California that year, one-half million acres had been seeded to non-native species, more than 5 million acres were on sites for which no condition guides had been written, and 11 million acres were annual grasslands. The 1982 estimate for range condition in California is shown in table 3.1.

Rangeland conditions in Washington and Oregon are very similar. The 1992 estimates show at least one-third of the land is in excellent or good condition and another one-third is in fair condition (table 3.1). Because measured trend is improving, range condition on private lands in the Pacific Northwest is judged to be in an upward trend.

## Rocky Mountain Region

For purposes of discussing rangeland condition, the 11 states in the Rocky Mountain (RM) Assessment Region are divided into the states dominated by mountains, valleys, and cold desert steppes (mountain states) and the states exclusively found on the Great Plains (plains states).

Condition of non-federal rangeland in the mountain states was characterized as improving more slowly than in other western states, with only 1 acre in 20 being in excellent condition. However, only 1 acre in 10 was in poor condition in 1992, indicating at least 80 percent of the land was clustered into the two middle condition categories, good and fair. This ranking had not changed much since 1982, although trends subjectively appeared

**Table 3.1**—Range condition on non-federal rangelands, 1982 and 1992: Pacific Coast Assessment Region (acres $10^3$ and percent of total area for which condition ratings were applied).

| State | Condition Class | Year 1982 | | Year 1992 | |
|---|---|---|---|---|---|
| California | Excellent | 29 | 2% | | NA |
| | Good | 473 | 31% | | |
| | Fair | 613 | 40% | | |
| | Poor | 434 | 28% | | |
| Oregon | Excellent | 226 | 2% | 625 | 7% |
| | Good | 1,813 | 20% | 2,404 | 27% |
| | Fair | 3,486 | 38% | 3,073 | 34% |
| | Poor | 3,731 | 40% | 2,855 | 32% |
| | Other[1] | 136 | | 418 | |
| Washington | Excellent | 629 | 11% | 689 | 13% |
| | Good | 1,169 | 21% | 1,567 | 29% |
| | Fair | 1,816 | 33% | 1,617 | 30% |
| | Poor | 1,933 | 35% | 1,542 | 28% |
| | Other | 90 | | 61 | |
| Total | Excellent | 855 | 6% | 1,314 | 9% |
| | Good | 2,982 | 20% | 3,971 | 27% |
| | Fair | 5,302 | 36% | 4,690 | 33% |
| | Poor | 5,664 | 38% | 4,397 | 31% |
| | Other | 226 | | 479 | |

*NA = Data not available.*

*[1] "Other" indicates land for which range condition guides are not available.*

to be slightly upwards (table 3.2). Montana seemed to stand alone in having vegetation distributions approaching later seral stages (table 3.2).

Non-federal lands in the plains states were in substantially better rangeland condition than the mountain states in 1992, with surprisingly large movements from good to excellent condition during the 10 years since 1982 (table 3.3). North Dakota was an anomaly, perhaps responding in part to the recent accelerated spread of weeds in the northern plains (Bangsund and Leistritz 1991).

The overall rangeland condition on non-federal lands for the RM Assessment Region is shown in table 3.4.

## South Region

Only three states in the South (SO) Assessment Region were sampled during the 1992 supplemental study—Florida, Oklahoma, and Texas. On the other hand, these three states contains approximately 62 percent of all grazed AUM's in the SO Assessment Region (table 3.5). The states, consequently, somewhat reflect overall conditions in the region by their weighted importance.

**Table 3.2**—Range condition on non-federal rangelands, 1982 and 1992: Rocky Mountain Assessment Region, mountain states (acres $10^3$ and percent of total area for which condition ratings were applied ).

| State | Condition Class | Year 1982 | | Year 1992 | |
|---|---|---|---|---|---|
| Arizona | Excellent | 518 | 2% | 650 | 2% |
| | Good | 4,923 | 16% | 8,446 | 27% |
| | Fair | 16,574 | 54% | 15,886 | 50% |
| | Poor | 8,832 | 28% | 6,661 | 21% |
| | Other[1] | 101 | | 584 | |
| Colorado | Excellent | 333 | 1% | 371 | 2% |
| | Good | 5,803 | 24% | 9,399 | 41% |
| | Fair | 14,012 | 58% | 10,462 | 45% |
| | Poor | 4,033 | 17% | 2,872 | 12% |
| | Other | 41 | | 433 | |
| Idaho | Excellent | 323 | 5% | 242 | 4% |
| | Good | 2,187 | 35% | 2,187 | 35% |
| | Fair | 2,566 | 40% | 2,420 | 39% |
| | Poor | 1,255 | 20% | 1,357 | 22% |
| | Other | 402 | | 462 | |
| Montana | Excellent | 5,028 | 13% | 3,905 | 11% |
| | Good | 17,272 | 46% | 17,233 | 47% |
| | Fair | 12,605 | 34% | 14,048 | 38% |
| | Poor | 2,727 | 7% | 1,361 | 4% |
| | Other | 185 | | 288 | |
| Nevada | Excellent | 239 | 3% | 386 | 5% |
| | Good | 2,674 | 35% | 2,913 | 40% |
| | Fair | 4,027 | 53% | 3,208 | 44% |
| | Poor | 659 | 9% | 780 | 11% |
| | Other | 309 | | 567 | |
| New Mexico | Excellent | 659 | 2% | 591 | 2% |
| | Good | 12,262 | 30% | 14,314 | 36% |
| | Fair | 22,617 | 55% | 21,227 | 53% |
| | Poor | 5,422 | 13% | 3,645 | 9% |
| | Other | 22 | | 15 | |
| Utah | Excellent | 155 | 2% | 303 | 3% |
| | Good | 1,724 | 21% | 2,188 | 23% |
| | Fair | 4,027 | 48% | 4,322 | 46% |
| | Poor | 2,451 | 29% | 2,563 | 27% |
| | Other | 132 | | 46 | |
| Wyoming | Excellent | 331 | 1% | 1,853 | 7% |
| | Good | 11,610 | 43% | 12,047 | 46% |
| | Fair | 13,988 | 52% | 10,761 | 42% |
| | Poor | 976 | 4% | 1,308 | 5% |
| | Other | 10 | | 46 | |
| Total | Excellent | 7,586 | 4% | 8,301 | 5% |
| | Good | 58,455 | 32% | 68,727 | 38% |
| | Fair | 90,416 | 50% | 82,334 | 46% |
| | Poor | 26,375 | 14% | 20,547 | 11% |
| | Other | 1,202 | | 3,069 | |

*[1] "Other" indicates land for which range condition guides are not available.*

**Table 3.3**—Range condition on non-federal rangelands, 1982 and 1992: Rocky Mountain Assessment Region, plains states (acres $10^3$ and percent of total area for which condition ratings were applied).

| State | Condition Class | 1982 | | 1992 | |
|---|---|---|---|---|---|
| Kansas | Excellent | 966 | 6% | 1,820 | 12% |
| | Good | 8,092 | 48% | 6,934 | 44% |
| | Fair | 6,122 | 36% | 5,832 | 37% |
| | Poor | 1,666 | 10% | 1,137 | 7% |
| | Other[1] | 63 | | 0 | |
| Nebraska | Excellent | 2,189 | 9% | 4,501 | 20% |
| | Good | 12,636 | 55% | 10,527 | 47% |
| | Fair | 7,110 | 31% | 6,303 | 28% |
| | Poor | 1,069 | 5% | 1,178 | 5% |
| | Other | 92 | | 160 | |
| North Dakota | Excellent | 1,524 | 14% | 1,130 | 11% |
| | Good | 6,295 | 57% | 5,096 | 51% |
| | Fair | 2,761 | 25% | 2,984 | 30% |
| | Poor | 368 | 3% | 872 | 8% |
| | Other | 0 | | 243 | |
| South Dakota | Excellent | 1,877 | 8% | 3,804 | 17% |
| | Good | 13,716 | 60% | 10,736 | 49% |
| | Fair | 6,486 | 29% | 6,687 | 31% |
| | Poor | 704 | 3% | 566 | 3% |
| | Other | 1 | | 140 | |
| Total | Excellent | 6,556 | 9% | 11,255 | 16% |
| | Good | 40,739 | 55% | 33,293 | 48% |
| | Fair | 22,479 | 30% | 21,806 | 31% |
| | Poor | 3,807 | 5% | 3,753 | 5% |
| | Other | 156 | | 543 | |

*[1] "Other" indicates land for which range condition guides are not available.*

**Table 3.4**—Range condition on non-federal rangelands, 1982 and 1992: Rocky Mountain Assessment Region (acres $10^3$ and percent of total area for which condition ratings were applied).

| Condition Class | 1982 | | 1992 | |
|---|---|---|---|---|
| Excellent | 14,142 | 5% | 19,556 | 8% |
| Good | 99,194 | 39% | 102,020 | 41% |
| Fair | 112,895 | 44% | 104,140 | 41% |
| Poor | 30,182 | 12% | 24,300 | 10% |
| Other[1] | 1,358 | | 3,612 | |

*[1] "Other" indicates land for which range condition guides are not available.*

**Table 3.5**—Forage consumption estimates in the Southern Assessment Region, based upon the January 1993 inventory of beef cattle. Source: USDA National Agricultural Statistics Service (1995).

| Region | Animals $10^3$ | AUM's $10^3$ |
|---|---|---|
| FL, OK, and TX | 14,560 | 174,720 |
| Southern Assessment Region | 23,467 | 281,604 |
| Percent of total | | 62% |

Florida ranks as having more non-federal rangeland unlike its associated climax communities than any other state in the conterminous U.S. (table 3.6). More than one-half of Florida rangeland was estimated to be in poor condition in 1992 by the NRCS supplemental study, and the proportion of land in poor condition increased by approximately 350,000 acres during the prior decade. No scientific basis has been proposed for such a rapid decline, but weed infestations, expansion of urban areas and attendant lowering of freshwater aquifers, and regulation of controlled fires may be adversely impacting the physical environment (Mullahey et al. 1994, Collins and Freeman 1996, Breininger and Schmalzer 1990).

Texas' non-federal rangelands were more degraded, according to the 1992 supplemental study, than any other Great Plains state (table 3.6). Since federal lands comprise less than 2 percent of Texas, these estimates essentially apply to the entire state (USDI Bureau of Land Management 1997a).

Collectively, non-federal rangeland in the three states in the SO Assessment Region are in earlier successional status than either the PC or RM Assessment Regions (table 3.6).

### North Region

There are only 130,000 acres of native rangeland in the North (NO) Assessment Region, nearly all of it in Missouri (table 2.4). This does not constitute an adequate land base to warrant discussion in a national assessment.

## Condition of Federal Rangelands

The condition of rangelands administered by the U.S. government is a subject of great interest and contention. Grazing is the most widespread land management practice on western public lands, and the results of public grazing policy, both past and present, are coming under increasing scrutiny (Council for Agricultural Science and

**Table 3.6—**Range condition on non-federal rangelands, 1982 and 1992: Southern Assessment Region (acres 10³ and percent of total area for which condition ratings were applied).

| State | Condition Class | Year | | | |
|---|---|---|---|---|---|
| | | 1982 | | 1992 | |
| Florida | Excellent | 25 | 1% | 19 | 1% |
| | Good | 273 | 7% | 171 | 5% |
| | Fair | 1,831 | 49% | 1,196 | 35% |
| | Poor | 1,640 | 43% | 2,003 | 59% |
| | Other[1] | 35 | | 78 | |
| Oklahoma | Excellent | 907 | 6% | 1,749 | 12% |
| | Good | 3,601 | 24% | 4,492 | 32% |
| | Fair | 7,639 | 51% | 5,835 | 42% |
| | Poor | 2,904 | 19% | 1,951 | 14% |
| | Other | 9 | | 34 | |
| Texas | Excellent | 480 | 1% | 174 | <1% |
| | Good | 13,546 | 15% | 16,324 | 18% |
| | Fair | 53,543 | 57% | 49,899 | 55% |
| | Poor | 25,681 | 27% | 24,922 | 27% |
| | Other | 2,103 | | 2,926 | |
| Total | Excellent | 1,412 | 1% | 1,942 | 2% |
| | Good | 17,420 | 16% | 20,987 | 19% |
| | Fair | 63,013 | 56% | 56,930 | 52% |
| | Poor | 30,225 | 27% | 28,876 | 27% |
| | Other | 2,147 | | 3,038 | |

*NA = Data not available.*
*[1] "Other" indicates land for which range condition guides are not available.*

Technology 1996). The two predominant opposing viewpoints are epitomized by Fleischner (1994) and Box (1990). Fleischner believes grazing has caused a loss of biodiversity, disruption of ecosystem function, and irreversible changes in ecosystem structure, while Box concludes that the trend of U.S. public rangelands, on the average, has been upwards over a number of decades and the land is in the best ecological condition of this century.

The following report on condition of public rangelands can neither judge nor mediate the disparity in perspectives about their perceived status. It simply conveys information provided by the responsible agencies, in this case the BLM and Forest Service.

## Lands Managed by the Bureau of Land Management

Until the mid-1970's, the BLM used various qualitative methods for assessing range condition (Wagner 1989). In 1977, the agency adopted a range site concept for its inventory procedure, called Soil-Vegetation Inventory Method (SVIM) (USDI Bureau of Land Management 1979). Five years later, the BLM changed to the Ecological Site Inventory (ESI) Procedure used by the Soil Conservation Service (USDA Soil Conservation Service 1976, USDI Bureau of Land Management 1984).

Since implementing SVIM and, later, ESI, the BLM has been inventorying its rangelands and classifying condition into four ecological status categories: Potential natural community (PNC, Küchler 1964), late seral, mid-seral, and early seral. These categories correspond to 76–100, 51–75, 26–50, and 0–25 percent similarity, respectively, of the PNC species structure on a biomass basis (USDI Bureau of Land Management 1985). To date, the BLM has inventoried 85.7 million acres under SVIM/ESI, or about one-half of its rangelands (USDI Bureau of Land Management 1997a).

In the decade since the 1989 range assessment (Joyce 1989), rangeland condition on BLM lands has not measurably changed in either the RM or the PC Assessment Region (table 3.7 and table 3.8). The results are consistent, even though the inventory methods have changed, as explained above. The BLM has no rangelands in the two eastern assessment regions.

### *Rocky Mountain Assessment Region*

Except for the southwestern states of Arizona and New Mexico, rangeland condition in the RM Assessment Region was fairly constant between 1986 and 1996 (USDI Bureau of Land Management 1987, 1997a). Arizona and, to a lesser extent, New Mexico both showed a greater increase in the areal extent of late seral communities and a decrease in the area of early seral communities (table 3.7).

### *Pacific Coast Assessment Region*

An initial scan of table 3.8 seems to indicate a dramatic decline in rangeland health in California since 1986. However, the 1986 statistics (USDI Bureau of Land Management 1987) included lands inventoried by five techniques: ESI, professional judgment, seeding, annual range, and other. If the non-ESI acres, which were deleted by the later report (USDI Bureau of Land Management 1997a), are added to the 1996 acres that were inventoried under ESI, the results show little percentage change from 1986 (unpublished data):

| CA BLM Lands | PNC | Late seral | Mid-seral | Early seral | Unclass |
|---|---|---|---|---|---|
| 1986 | 1% | 44% | 43% | 10% | 2% |
| 1996 | 3% | 40% | 37% | 15% | 5% |

**Table 3.7—**Range condition on Bureau of Land Management rangelands[1], 1986 and 1996: Rocky Mountain Assessment Region (acres $10^3$ and percent of total). Note: The acres and percentages by condition class shown for 1996 are based upon only those acres inventoried using the Soil-Vegetation Inventory Method or the Ecological Site Inventory (see text) and classified by condition.

| State | Condition Class | | Year 1986 | | Year 1996 |
|---|---|---|---|---|---|
| Arizona | PNC[2] | 467 | 4% | 521 | 9% |
| | Late seral | 2,801 | 24% | 2,217 | 40% |
| | Mid seral | 6,068 | 52% | 2,217 | 40% |
| | Early seral | 2,334 | 20% | 652 | 12% |
| | Unclassified | 0 | | 913 | |
| | Not Inventoried | | | 5,123 | |
| Colorado | PNC | 237 | 3% | 140 | 5% |
| | Late seral | 1,266 | 18% | 630 | 22% |
| | Mid seral | 3,403 | 48% | 1,260 | 45% |
| | Early seral | 2,216 | 31% | 770 | 28% |
| | Unclassified | 791 | | 700 | |
| | Not Inventoried | | | 3,792 | |
| Idaho | PNC | 417 | 4% | 182 | 2% |
| | Late seral | 3,193 | 29% | 2,002 | 24% |
| | Mid seral | 4,304 | 39% | 2,912 | 36% |
| | Early seral | 3,054 | 28% | 3,093 | 38% |
| | Unclassified | 2,916 | | 910 | |
| | Not Inventoried | | | 2,134 | |
| Montana | PNC | 397 | 6% | 481 | 7% |
| | Late seral | 4,764 | 67% | 4,329 | 68% |
| | Mid seral | 1,826 | 26% | 1,512 | 24% |
| | Early seral | 79 | 1% | 69 | 1% |
| | Unclassified | 873 | | 550 | |
| | Not Inventoried | | | 1,027 | |
| Nevada | PNC | 2,771 | 6% | 372 | 2% |
| | Late seral | 12,010 | 27% | 5,016 | 32% |
| | Mid seral | 19,400 | 43% | 8,360 | 52% |
| Nevada, cont. | Early seral | 10,624 | 24% | 2,229 | 14% |
| | Unclassified | 1,385 | | 2,787 | |
| | Not Inventoried | | | 29,056 | |
| New Mexico | PNC | 125 | 1% | 102 | 1% |
| | Late seral | 3,002 | 25% | 3,555 | 36% |
| | Mid seral | 6,003 | 50% | 4,673 | 48% |
| | Early seral | 2,877 | 24% | 1,422 | 15% |
| | Unclassified | 500 | | 305 | |
| | Not Inventoried | | | 2,540 | |
| Utah | PNC | 893 | 5% | 1,399 | 11% |
| | Late seral | 6,476 | 35% | 3,690 | 30% |
| | Mid seral | 8,486 | 45% | 5,471 | 45% |
| | Early seral | 2,903 | 15% | 1,654 | 14% |
| | Unclassified | 3,573 | | 509 | |
| | Not Inventoried | | | 8,482 | |
| Wyoming | PNC | 911 | 5% | 438 | 7% |
| | Late seral | 8,203 | 48% | 3,137 | 48% |
| | Mid seral | 6,745 | 40% | 2,481 | 38% |
| | Early seral | 1,094 | 7% | 438 | 7% |
| | Unclassified | 1,276 | | 803 | |
| | Not Inventoried | | | 7,904 | |
| Total | PNC | 6,218 | 4% | 3,635 | 5% |
| | Late seral | 41,715 | 32% | 24,576 | 37% |
| | Mid seral | 56,235 | 50% | 28,886 | 43% |
| | Early seral | 25,181 | 14% | 10,327 | 15% |
| | Unclassified | 800 | | 7,477 | |
| | Not Inventoried | | | 60,058 | |

*[1] Lands with grazing permits in grazing districts and lands with grazing leases (Section 15 lands).*
*[2] Potential Natural Community (see Küchler 1964; Glossary Update Task Group, Society for Range Management 1998).*

California is an unusual state because much of its rangeland is comprised of annual grassland, for which ESI classification guides do not exist.

### All BLM Lands

Condition of all lands managed by the BLM, taken together, was steady during the 10-year period, 1986 to 1996 (USDI Bureau of Land Management 1987, 1997a):

| All BLM Lands | PNC | Late seral | Mid-seral | Early seral | Unclass |
|---|---|---|---|---|---|
| 1986 | 4% | 31% | 41% | 17% | 7% |
| 1996 | 4% | 33% | 40% | 14% | 9% |

Of the land for which actual range condition determinations were made using ESI/SVIM, about 42 percent was in PNC or a late seral stage, 44 percent was at an intermediate successional state, and 14 percent was dominated by early seral vegetation (USDI Bureau of Land Management 1997b).

## Lands Managed by the Forest Service

In the last range assessment, Joyce (1989) reported upon the condition of rangelands managed by USDA Forest Service by Assessment Region in three different ways: (1) ecological status, using the same four categories as the BLM; (2) livestock forage value within ecological status; and (3) trend in ecological status. These

**Table 3.8—**Range condition on Bureau of Land Management rangelands[1], 1986 and 1996: Pacific Coast Assessment Region (acres $10^3$ and percent of total). Note: The acres and percentages by condition class shown for 1996 are based upon only those acres inventoried using the Soil-Vegetation Inventory Method or the Ecological Site Inventory (see text) and classified by condition.

| | | | Year | | |
|---|---|---|---|---|---|
| State | Condition Class | | 1986 | | 1996 |
| California | PNC[2] | 95 | 1% | 41 | 3% |
| | Late seral[3] | 4,201 | 45% | 273 | 21% |
| | Mid seral | 4,106 | 44% | 574 | 44% |
| | Early seral | 955 | 10% | 410 | 32% |
| | Unclassified | 191 | | 55 | |
| | Not Inventoried | | | 5,123 | |
| Oregon | PNC | 505 | 4% | 88 | 1% |
| | Late seral | 3,280 | 27% | 2,900 | 35% |
| | Mid seral | 6,308 | 52% | 4,218 | 50% |
| | Early seral | 2,145 | 17% | 1,142 | 14% |
| | Unclassified | 379 | | 351 | |
| | Not Inventoried | | | 4,328 | |
| CA and OR | PNC | 600 | 3% | 129 | 1% |
| | Late seral | 7,481 | 35% | 3,173 | 33% |
| | Mid seral | 10,414 | 48% | 4,792 | 50% |
| | Early seral | 3,100 | 14% | 1,552 | 16% |
| | Unclassified | 570 | | 406 | |
| | Not Inventoried | | | 9,451 | |

*[1] Lands with grazing permits in grazing districts and lands with grazing leases (Section 15 lands).*

*[2] Potential Natural Community (see Küchler 1964; Glossary Update Task Group, Society for Range Management 1998).*

*[3] For explanation of apparent decline of rangeland classified as late seral between 1986 and 1996, see text.*

estimates were derived from unpublished contents analyses of forest plans (figure 3.1). The same approach was not repeated for the present assessment because very few forest plans have been revised.

The Forest Service presently does not publish summaries of range condition, per se. Alternatively, the agency identifies areas of rangeland vegetation that meet, are progressing towards, or neither meet nor are progressing towards established Forest Plan Management Objectives (FPMO). Land is classified only in conformity with rangeland-related attributes of each forest plan. The three categories are comprised of lands that are monitored (thus, verified as being in that category) and unmonitored (estimated to be in that category). Upland and riparian lands are reported separately.

There is at least one difficulty associated with categorizing rangeland health in terms of FPMO's: most National Forests are still operating under the first round of forest plans approved in the 1980's, and the elements relating to rangeland health are not well correlated to trends in indicators judged to be relevant by contemporary standards (Committee on Rangeland Classification 1994). For example, numerous forest plans employ utilization standards as criteria to limit livestock grazing use to that believed necessary to maintain or improve targeted rangelands (USDA Forest Service 1985). Yet, some observers consider this approach, in a de facto manner, also is unduly being used to monitor changes needed to determine if overall FPMO's are being met (Sanders 1998).

Even though the Forest Service expressed range condition by an indirect ordinal measure (proportion of land in relation to FPMO's), the results probably portray conditions at a national scale with reasonable accuracy. Hierarchy theory postulates that ecosystem processes and characteristics, including those relating to sustainability, differ according to the temporal and spatial scale on which they are organized (Allen and Starr 1982, O'Neill 1989). Slow-changing, generalized features have been incorporated into indicators of forest health at a national level as part of the Montreal Process (Coulombe 1995). The Forest Service findings on range condition fit this classification.

## *Pacific Coast Assessment Region*

The PC Assessment Region includes the Pacific Southwest (R-5) and Pacific Northwest Regions (R-6) of the Forest Service. As of 1998, all Forests in R-5 were still operating under their original plans, although several plans were completed after 1992 and two Forests had completed range-related amendments to their plans. The Forests in R-6 were in the same situation in 1998, except that the 17 National Forests west of the summit of the Cascade Mountains fell under the authority of the Northwest Forest Plan covering the protection of spotted owl and anadromous fish habitats (USDA Forest Service, Pacific Northwest Region 1998). East of the Cascade Mountains summit, Forest plans were subject to restrictions for managing riparian zones and contiguous uplands for anadromous and native fish species by two interim strategies, PACFISH and INFISH (Pacific States Marine Fisheries Commission 1995).

The area of upland rangeland vegetation within grazing allotments falling in the three categories relating to FPMO's is depicted by Forest Service Region (table 3.9 and table 3.10). For the entire PC Assessment Region, approximately 95 percent of rangeland within grazing allotments is either meeting or progressing towards FPMO's (table 3.11). The only difference between R-5 and R-6 is the fraction of land that already meets FPMO's, two-thirds and one-half, respectively.

The 5 percent of lands not meeting nor progressing towards FPMO's is less than the 15 percent of lands esti-

**Figure 3.1—**Well-managed fescue grassland on the Pike National Forest, Colorado. This allotment is in a desired ecological state and has high forage value, as called for in the Forest Plan.

**Table 3.9—**Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Pacific Southwest Region — CA (acres $10^3$).

| | Year | | |
|---|---|---|---|
| Land Category | 1995 | 1996 | 1997 |
| Total range vegetation | 7,055 | 6,775 | 7,121 |
| Having range vegetation management objectives | 7,055 | 6,760 | 7,106 |
| Monitored during current year | 1,806 | 1,784 | 1,626 |
| Verified meeting FPMO | 809 | 855 | 841 |
| Estimated meeting FPMO | 1,682 | 1,641 | 1,650 |
| Total | 2,491 (67%) | 2,496 (67%) | 2,491 (68%) |
| Verified moving toward FPMO | 250 | 261 | 243 |
| Estimated moving toward FPMO | 786 | 788 | 737 |
| Total | 1,036 (28%) | 1,049 (28%) | 980 (27%) |
| Verified not meeting or moving toward FPMO | 28 | 27 | 28 |
| Estimated not meeting or moving toward FPMO | 178 | 178 | 139 |
| Total | 206 (5%) | 205 (5%) | 167 (5%) |
| Undetermined status | 3,322 | 3,025 | 3,483 |

mated to be in early-seral stage or moving away from PNC in 1986 (Joyce 1989). Since the two approaches are not comparable, however, no conclusions concerning trend in condition can be drawn.

## *Rocky Mountain Assessment Region*

The RM Assessment Region includes four Forest Service Regions: Northern (R-1), Rocky Mountain (R-2), Southwest (R-3), and Intermountain (R-4) (figure 1.5). As of 1998, all Forests in R-1 were operating on first-round plans with no significant rangeland-related amendments. In R-2, 4 out of 10 Forests had new forest plans. In R-3, all Forests were still operating on their original plans, although the forest plans were amended in 1996 to add updated grazing utilization standards. In R-4, all Forests but three were operating on their original plans; one had a revised plan and two had range-related amendments.

The area of upland rangeland vegetation within grazing allotments falling in the three categories relating to FPMO's is depicted by Forest Service Region (table 3.12 through table 3.15). By the standards described herein,

**Table 3.10—**Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Pacific Northwest Region — OR, WA (acres $10^{3}$).

| Land Category | Year 1995 | 1996 | 1997 |
|---|---|---|---|
| Having range vegetation management objectives | 10,383 | 10,252 | 10,243 |
| Monitored during current year | 3,249 | 3,262 | 2,822 |
| Verified meeting FPMO | 742 | 710 | 665 |
| Estimated meeting FPMO | 2,840 | 2,812 | 2,872 |
| Total | 3,582 (49%) | 3,522 (50%) | 3,537 (51%) |
| Verified moving toward FPMO | 432 | 368 | 201 |
| Estimated moving toward FPMO | 2,870 | 2,930 | 2,978 |
| Total | 3,302 (45%) | 3,298 (46%) | 3,179 (45%) |
| Verified not meeting or moving toward FPMO | 84 | 62 | 58 |
| Estimated not meeting or moving toward FPMO | 353 | 231 | 232 |
| Total | 437 (6%) | 293 (4%) | 290 (4%) |
| Undetermined status | 3,075 | 3,139 | 3,237 |

**Table 3.11—**Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Pacific Coast Assessment Region (acres $10^{3}$).

| Land Category | Year 1995 | 1996 | 1997 |
|---|---|---|---|
| Having range vegetation management objectives | 17,438 | 17,012 | 17,349 |
| Monitored during current year | 5,055 | 5,046 | 4,448 |
| Verified meeting FPMO | 1,551 | 1,565 | 1,506 |
| Estimated meeting FPMO | 4,522 | 4,453 | 4,522 |
| Total | 6,073 (55%) | 6,018 (55%) | 6,028 (57%) |
| Verified moving toward FPMO | 682 | 629 | 444 |
| Estimated moving toward FPMO | 3,656 | 3,718 | 3,715 |
| Total | 4,338 (39%) | 4,347 (40%) | 4,159 (39%) |
| Verified not meeting or moving toward FPMO | 112 | 89 | 86 |
| Estimated not meeting or moving toward FPMO | 531 | 409 | 371 |
| Total | 643 (6%) | 498 (5%) | 457 (4%) |
| Undetermined status | 6,384 | 6,149 | 6,705 |

**Table 3.12**—Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Northern Region — MT, northern ID, ND, northwest SD (acres $10^3$).

| | Year | | | | | |
|---|---|---|---|---|---|---|
| Land Category | 1995 | | 1996 | | 1997 | |
| Having range vegetation management objectives | 5,219 | | 4,660 | | 4,664 | |
| Monitored during current year | 1,376 | | 1,288 | | 1,300 | |
| Verified meeting FPMO | 157 | | 160 | | 192 | |
| Estimated meeting FPMO | 3,197 | | 2,841 | | 2,832 | |
| Total | 3,354 | (64%) | 3,001 | (64%) | 3,024 | (65%) |
| Verified moving toward FPMO | 45 | | 45 | 48 | | |
| Estimated moving toward FPMO | 882 | | 822 | | 820 | |
| Total | 927 | (18%) | 867 | (19%) | 868 | (19%) |
| Verified not meeting or moving toward FPMO | 6 | | 5 | | 9 | |
| Estimated not meeting or moving toward FPMO | 933 | | 788 | | 763 | |
| Total | 939 | (18%) | 793 | (17%) | 772 | (16%) |
| Undetermined status | 0 | | 0 | | 0 | |

*Note: The total area having range management objectives for 1995 exceeds that for 1996 and 1997 because of a reporting error. The 1995 estimates assume the land mistakenly included was distributed in the same manner as the land appropriately included.*

**Table 3.13**—Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Rocky Mountain Region — CO, KS, NE, SD, eastern WY (acres $10^3$).

| | Year | | | | | |
|---|---|---|---|---|---|---|
| Land Category | 1995 | | 1996 | | 1997 | |
| Having range vegetation management objectives | 11,924 | | 11,435 | | 11,533 | |
| Monitored during current year | 2,621 | | 2,574 | | 2,830 | |
| Verified meeting FPMO | 2,358 | | 2,483 | | 2,781 | |
| Estimated meeting FPMO | 3,509 | | 3,306 | | 3,262 | |
| Total | 5,867 | (61%) | 5,789 | (64%) | 6,043 | (65%) |
| Verified moving toward FPMO | 533 | | 600 | | 583 | |
| Estimated moving toward FPMO | 2,496 | | 2,091 | | 2,066 | |
| Total | 3,029 | (32%) | 2,691 | (29%) | 2,649 | (29%) |
| Verified not meeting or moving toward FPMO | 124 | | 200 | | 141 | |
| Estimated not meeting or moving toward FPMO | 544 | | 446 | | 414 | |
| Total | 668 | (7%) | 646 | (7%) | 555 | (6%) |
| Undetermined status | 2,360 | | 2,309 | | 2,286 | |

the RM Assessment Region is clearly in less desirable condition than the PC and NO Assessment Regions: 15 percent of rangeland within grazing allotments is neither meeting nor moving towards FPMO's (table 3.16). This proportion conforms to the estimate of National Forest System (NFS) lands in early seral successional stages or progressing away from PNC in 1986 (Joyce 1989).

Vegetation in the mostly dry Southwestern Region has been subjected to a history of fire suppression since the late 19th Century and improper grazing, primarily between the 1880's and World War I (Secretary of Agriculture 1936, Rasmussen 1941, Cooper 1960, Buffington and Herbel 1965, Mortensen 1978). These factors and others have caused upland vegetation and soil changes that are slow to improve, some of which probably will not ever recover to pre-existing conditions (Schlesinger et al. 1990, Wang and Hacker 1997). As a result, the higher percentage of rangeland in R-3 that is not meeting or progress-

**Table 3.14—**Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Southwestern Region — AZ, NM (acres $10^3$).

| Land Category | Year 1995 | 1996 | 1997 |
|---|---|---|---|
| Having range vegetation management objectives | 18,320 | 18,332 | 18,019 |
| Monitored during current year | 4,859 | 6,348 | 6,364 |
| Verified meeting FPMO | 1,676 | 1,859 | 1,945 |
| Estimated meeting FPMO | 2,541 | 2,595 | 2,376 |
| Total | 4,217 (26%) | 4,454 (27%) | 4,321 (27%) |
| Verified moving toward FPMO | 1,486 | 1,456 | 1,455 |
| Estimated moving toward FPMO | 6,227 | 6,208 | 6,105 |
| Total | 7,713 (47%) | 7,664 (46%) | 7,560 (47%) |
| Verified not meeting or moving toward FPMO | 788 | 673 | 741 |
| Estimated not meeting or moving toward FPMO | 3,663 | 3,702 | 3,548 |
| Total | 4,451 (27%) | 4,375 (27%) | 4,289 (26%) |
| Undetermined status | 1,938 | 1,839 | 1,849 |

**Table 3.15—**Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Intermountain Region — Southern ID, NV, UT, western WY (acres $10^3$).

| Land Category | Year 1995 | 1996 | 1997 |
|---|---|---|---|
| Having range vegetation management objectives | 23,192 | 19,172 | 19,547 |
| Monitored during current year | 7,805 | 6,076 | 5,224 |
| Verified meeting FPMO | 2,068 | 2,090 | 2,321 |
| Estimated meeting FPMO | 6,483 | 5,548 | 5,771 |
| Total | 8,551 (46%) | 7,638 (48%) | 8,092 (49%) |
| Verified moving toward FPMO | 1,136 | 1,073 | 870 |
| Estimated moving toward FPMO | 7,511 | 5,899 | 6,361 |
| Total | 8,647 (47%) | 6,972 (44%) | 7,231 (43%) |
| Verified not meeting or moving toward FPMO | 87 | 64 | 70 |
| Estimated not meeting or moving toward FPMO | 1,305 | 1,304 | 1,284 |
| Total | 1,392 (7%) | 1,368 (8%) | 1,354 (8%) |
| Undetermined status | 4,602 | 3,194 | 2,870 |

*Note: The total area of range vegetation for 1995 exceeds that for 1996 and 1997 because of a reporting error. The 1995 estimates assume the land mistakenly included was distributed in the same manner as the land appropriately included.*

ing towards FPMO's, roughly 25 percent, should not be surprising (table 3.14).

## *South Assessment Region*

The SO Assessment Region includes only one Forest Service Region, the Southern (R-8). Fourteen Forests are operating on first-round plans, two of which have significant revisions, and four Forests have revised forest plans.

Table 3.17 suggests an apparent trend of decreasing land moving towards FPMO's and increasing land that neither meets nor moves towards FPMO's for NFS rangelands in R-8. However, unpublished information (personal communication, Mr. Levester Pendergrass, R-8, Atlanta, GA) indicates the 1997 data in the table represent stable conditions that have actually changed little over the past decade. The 16 percent of NFS rangelands in grazing allotments that are not meeting nor progressing towards FPMO's puts it on a par with the RM Assessment Region.

## North Assessment Region

The NO Assessment Region also includes only one Forest Service Region, the Eastern (R-9). The Eastern Region has 15 Forests operating under their original plans, and none has a significant revision related to rangelands. Rangelands in R-9 are in exemplary condition in relation to FPMO's (table 3.18). Less than 5 percent of range vegetation within grazing allotments is not meeting nor progressing towards management goals. The large disparity between areas meeting FPMO's versus areas moving toward FPMO's represents, like that described above for the SO Assessment Region, a correction resulting from more complete verification and improved estimates of the actual status of land in grazing allotments (personal communication with Ken Holtje, R-9, Milwaukee, WI).

## All NFS Lands

Even though the current protocol for appraising range condition is fundamentally different from that used for the

**Table 3.16—**Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Rocky Mountains Assessment Region (acres $10^3$).

| | Year | | |
|---|---|---|---|
| Land Category | 1995 | 1996 | 1997 |
| Having range vegetation management objectives | 58,655 | 53,599 | 53,763 |
| Monitored during current year | 16,661 | 16,286 | 15,718 |
| Verified meeting FPMO | 6,259 | 6,592 | 7,239 |
| Estimated meeting FPMO | 15,730 | 14,290 | 14,241 |
| Total | 21,989 (44%) | 20,882 (45%) | 21,480 (46%) |
| Verified moving toward FPMO | 3,200 | 3,174 | 2,956 |
| Estimated moving toward FPMO | 17,116 | 15,020 | 15,352 |
| Total | 20,316 (41%) | 18,194 (39%) | 18,308 (39%) |
| Verified not meeting or moving toward FPMO | 1,005 | 942 | 961 |
| Estimated not meeting or moving toward FPMO | 6,445 | 6,240 | 6,009 |
| Total | 7,450 (15%) | 7,182 (16%) | 6,970 (15%) |
| Undetermined status | 8,900 | 7,341 | 7,005 |

**Table 3.17—**Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): South Assessment Region (acres $10^3$).

| | Year | | |
|---|---|---|---|
| Land Category | 1995 | 1996 | 1997 |
| Having range vegetation management objectives | 1,523 | 1,262 | 1,169 |
| Monitored during current year | 238 | 269 | 250 |
| Verified meeting FPMO | 405 | 421 | 370 |
| Estimated meeting FPMO | 546 | 500 | 473 |
| Total | 951 (76%) | 921 (82%) | 843 (76%) |
| Verified moving toward FPMO | 1 | 16 | 51 |
| Estimated moving toward FPMO | 286 | 147 | 32 |
| Total | 287 (23%) | 163 (14%) | 83 (8%) |
| Verified not meeting or moving toward FPMO | 0 | 7 | 7 |
| Estimated not meeting or moving toward FPMO | 21 | 39 | 170 |
| Total | 21 (1%) | 46 (4%) | 177 (16%) |
| Undetermined status | 264 | 132 | 66 |

last Assessment, two factors allow one to accept the null hypothesis that rangeland health of uplands on NFS lands is fairly static: (1) the lack of any short-term trend between 1995 and 1997, and (2) the congruity of results presented above with Joyce's (1989) general conclusions showing only about one acre in seven on NFS lands in a less than satisfactory ecological condition or downward trend.

Rangeland health has clearly improved over the past 20 years, regardless of its present stable state, if conditions now are compared to those presented in the 1979 RPA Assessment document (USDA Forest Service 1980). Although it did not separate NFS lands, the 1979 Assessment estimated that at least half of all rangelands were in poor or very poor condition. And, in the Rocky Mountain states where most NFS rangelands are situated, the percentage of rangelands in poor or very poor condition was nearly identical to the Nation as a whole.

Another consideration concerns the proportion of NFS land within grazing allotments that have an undetermined status, nearly 20 percent of the total. The percentages shown in parentheses in table 3.9 through table 3.19 are based upon only those lands that have been cate-

**Table 3.18**—Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): North Assessment Region (acres 10³).

| Land Category | 1995 | 1996 | 1997 |
|---|---|---|---|
| Having range vegetation management objectives | 66 | 66 | 65 |
| Monitored during current year | 63 | 63 | 48 |
| Verified meeting FPMO | 26 | 27 | 12 |
| Estimated meeting FPMO | 4 | 4 | 8 |
| Total | 30 (49%) | 31 (49%) | 20 (33%) |
| Verified moving toward FPMO | 24 | 24 | 9 |
| Estimated moving toward FPMO | 6 | 6 | 32 |
| Total | 30 (48%) | 30 (48%) | 41 (67%) |
| Verified not meeting or moving toward FPMO | 0 | 0 | 0 |
| Estimated not meeting or moving toward FPMO | 2 | 2 | 0 |
| Total | 2 (3%) | 2 (3%) | 0 (0%) |
| Undetermined status | 4 | 3 | 4 |

**Table 3.19**—Area of upland range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): All NFS lands (acres 10³).

| Land Category | 1995 | 1996 | 1997 |
|---|---|---|---|
| Having range vegetation management objectives | 77,682 | 71,939 | 72,346 |
| Monitored during current year | 22,017 | 21,664 | 20,464 |
| Verified meeting FPMO | 8,241 | 8,578 | 9,127 |
| Estimated meeting FPMO | 20,802 | 19,247 | 19,247 |
| Total | 29,043 (47%) | 27,825 (48%) | 28,374 (49%) |
| Verified moving toward FPMO | 3,907 | 3,843 | 3,460 |
| Estimated moving toward FPMO | 21,064 | 18,891 | 19,131 |
| Total | 24,971 (40%) | 22,734 (39%) | 22,591 (38%) |
| Verified not meeting or moving toward FPMO | 1,117 | 1,038 | 1,054 |
| Estimated not meeting or moving toward FPMO | 6,999 | 6,690 | 6,550 |
| Total | 8,116 (13%) | 7,728 (13%) | 7,604 (13%) |
| Undetermined status | 15,552 | 13,625 | 13,780 |

gorized; thus, they sum to 100 percent in each column. These percentages assume that allotments yet to be categorized will follow the same distribution as those which have been categorized. Such an assumption obviously may not be true.

The low level of funding for rangeland vegetation management and grazing management programs on NFS lands may be contributing to the static nature of range condition in recent years. According to unpublished information provided by the Forest Service Washington Office Range Staff, the regional distribution of appropriated rangeland vegetation and grazing management funds remained fairly stagnant throughout the 1990's at a level only adequate to pay administrative costs for managing most NFS grazing programs. In the Pacific Northwest Region, where about one-half of allotments are subject to the terms and conditions contained in biological opinions, the current budget does not meet administrative costs (Personal communication with Richard Lindenmuth, Pacific Northwest Region, USDA Forest Service, Portland, OR). Therefore, the only funds used by the Regions for actual rangeland improvements were range betterment funds returned from grazing fees. Because of declining grazing fees (based upon P.L. 95-514, Public Rangelands Improvement Act of 1978), total range betterment funding declined from $5.3 million in 1993 to $3.1 million in 1998.

## Riparian Areas

In March 1996, the Chief of the Forest Service and the Director of the BLM, in cooperation with NRCS, initiated an interagency strategy for "accelerating cooperative riparian restoration and management" starting in the 11 western states. This approach is based on the premise that restoration and management must be addressed on a watershed scale in cooperation with all landowners in order to be successful. The emphasis is also on problem resolution at the ground level by the people most affected by success or failure. The interagency commitment included formation of a National Riparian Service Team (NRST), headquartered in Prineville, OR, to promote and lead this collaborative effort.

The Proper Functioning Condition (PFC) assessment was selected as the foundation tool to help people of diverse backgrounds focus initially on the physical function of riparian-wetland areas rather than values produced, such as habitat, forage, etc. This provides an effective first step toward development of cooperative management plans, and also helps guide restoration and monitoring priorities. The PFC assessment is intended to be performed by a journey level, interdisciplinary team that includes specialists in vegetation, soils, and hydrology (Barrett et al. 1995, Bridges et al. 1994). This method relies on a qualitative checklist, supported by quantitative sampling techniques where answers are uncertain or where experience is limited.

The on-the-ground condition termed PFC refers to how well the physical processes are functioning. The PFC assessment is designed to determine four defined states: proper functioning condition, functional-at risk, nonfunctional, and unknown. PFC is a state of resiliency that will allow a riparian-wetland area to hold together during moderately high flow events, sustaining that system's ability to produce values related to both physical and biological attributes. PFC does not automatically indicate a desired (future) condition, but is always a prerequisite to achieving desired condition.

Both the BLM and Forest Service have been collecting data on the status of riparian areas for a number of years. Beginning with their Riparian-Wetland Initiative for the 1990's (USDI Bureau of Land Management 1991), BLM began assessing and reporting riparian condition in terms of PFC status. The Forest Service, through direction outlined in "Riparian Management — A Leadership Challenge" (Robertson 1992), uses the same reporting method it employs for uplands. For rangelands, that includes the number of acres within grazing allotments meeting, moving towards, or neither meeting nor moving towards forest plan objectives.

### *BLM Lands*

The status of riparian areas on BLM lands in 1997 is reported by state and assessment region in table 3.20. For all BLM lands in the conterminous United States, 12,014 miles (41 percent) are at PFC, 12,888 miles (45 percent) are functional but at risk, and 3,965 miles (14 percent) are non-functional. One-fourth (9,854 miles) of BLM streams have not been inventoried for condition, so their status is unknown (USDI Bureau of Land Management 1997a). In 1995, 11,352 miles had not been inventoried in the same western states (USDI Bureau of Land Management 1995). The Agency has an ambitious plan to inventory and classify its riparian areas and wetlands, so succeeding Assessments should contain more complete information (USDI Bureau of Land Management 1991). All surveys are to be completed during fiscal year 2000, and a sample of functional-at risk systems where management changes have been made will be re-analyzed for the purpose of determining resultant trends (Personal communication, NRST).

### *NFS Lands*

The status of riparian condition varies among assessment regions. In the PC Assessment Region, about 10 percent of the area of riparian rangeland vegetation within grazing allotments is neither meeting nor moving towards

**Table 3.20—**Status of riparian areas on BLM lands in 1997 that have been classified using Proper Functioning Condition (PFC) (Barrett et al. 1995).

| | PFC Condition Class | | | | | |
|---|---|---|---|---|---|---|
| | PFC | | Functioning-at risk | | Non-functional | |
| State/Assessment Region | Miles | Percent | Miles | Percent | Miles | Percent |
| California | 1,750 | 61 | 1,023 | 36 | 87 | 3 |
| Oregon/Washington | 1,575 | 49 | 1,469 | 45 | 197 | 6 |
| Pacific Coast Assessment Region | 3,325 | 54 | 2,492 | 41 | 284 | 5 |
| Arizona | 290 | 39 | 436 | 58 | 21 | 3 |
| Colorado | 1,942 | 48 | 1,415 | 35 | 700 | 17 |
| Idaho | 932 | 41 | 966 | 43 | 352 | 16 |
| Montana | 2,048 | 43 | 2,225 | 46 | 523 | 11 |
| Nevada | 361 | 26 | 543 | 38 | 513 | 36 |
| New Mexico | 137 | 33 | 184 | 45 | 88 | 22 |
| Utah | 1,657 | 46 | 1,447 | 40 | 502 | 14 |
| Wyoming | 1,322 | 24 | 3,180 | 58 | 982 | 18 |
| Rocky Mountains Assessment Region | 8,689 | 38 | 10,396 | 46 | 3,681 | 16 |

*Source: USDI Bureau of Land Management (1998)*

**Table 3.21—**Area of riparian range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Pacific Coast Assessment Region (acres $10^2$).

| | Year | | |
|---|---|---|---|
| Land Category | 1995 | 1996 | 1997 |
| Having range vegetation management objectives | 7,983 | 7,922 | 7,854 |
| Monitored during current year | 2,317 | 2,241 | 1,940 |
| Verified meeting FPMO | 867 | 948 | 796 |
| Estimated meeting FPMO | 1,886 | 1,823 | 1,528 |
| Total | 2,753 (50%) | 2,771 (51%) | 2,324 (45%) |
| Verified moving toward FPMO | 594 | 450 | 407 |
| Estimated moving toward FPMO | 1,408 | 1,754 | 1,939 |
| Total | 2,002 (36%) | 2,204 (40%) | 2,346 (46%) |
| Verified not meeting or moving toward FPMO | 176 | 120 | 126 |
| Estimated not meeting or moving toward FPMO | 598 | 342 | 343 |
| Total | 774 (14%) | 462 (9%) | 469 (9%) |
| Undetermined status | 2,454 | 2,485 | 2,715 |

FPMO (table 3.21). As mentioned above, it should be noted that three working strategies for protecting and restoring anadromous and native fish habitats, the Northwest Forest Plan, PACFISH, and INFISH, have effectively modified Forest plans throughout the Pacific Northwest Region.

In the RM Assessment Region, about one riparian acre in six does not meet nor is progressing towards FPMO (table 3.22). Interestingly, this is the same proportion as was reported as being nonfunctional by the BLM for their riparian lands in the RM Assessment Region (table 3.20).

Both the SO and NO Assessment Regions contain very little riparian range vegetation, and nearly all of these lands already meet FPMO (table 3.23 and table 3.24).

There are several reasons why the condition of riparian areas in arid and semi-arid regions can improve more quickly than associated uplands. Because of vegetation and physical characteristics reflective of permanent sur-

**Table 3.22**—Area of riparian range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): Rocky Mountains Assessment Region (acres $10^2$).

| | Year | | |
|---|---|---|---|
| Land Category | 1995 | 1996 | 1997 |
| Having range vegetation management objectives | 16,340 | 15,317 | 15,760 |
| Monitored during current year | 4,935 | 4,169 4,400 | |
| Verified meeting FPMO | 1,391 | 1,450 | 1,777 |
| Estimated meeting FPMO | 4,549 | 4,421 | 4,662 |
| Total | 5,940 (42%) | 5,871 (45%) | 6,439 (47%) |
| Verified moving toward FPMO | 922 | 858 | 875 |
| Estimated moving toward FPMO | 4,519 | 3,973 | 4,092 |
| Total | 5,441 (39%) | 4,831 (37%) | 4,967 (37%) |
| Verified not meeting or moving toward FPMO | 402 | 266 | 208 |
| Estimated not meeting or moving toward FPMO | 2,226 | 2,059 | 1,905 |
| Total | 2,628 (19%) | 2,325 (18%) | 2,113 (16%) |
| Undetermined status | 2,331 | 2,290 | 2,241 |

**Table 3.23**—Area of riparian range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): South Assessment Region (acres $10^2$).

| | Year | | |
|---|---|---|---|
| Land Category | 1995 | 1996 | 1997 |
| Having range vegetation management objectives | 654 | 609 | 597 |
| Monitored during current year | 38 | 33 | 28 |
| Verified meeting FPMO | 68 | 67 | 65 |
| Estimated meeting FPMO | 241 | 206 | 199 |
| Total | 309 (82%) | 273 (79%) | 264 (79%) |
| Verified moving toward FPMO | 10 | 6 | 6 |
| Estimated moving toward FPMO | 58 | 42 | 39 |
| Total | 68 (18%) | 48 (14%) | 45 (14%) |
| Verified not meeting or moving toward FPMO | 1 | 0 | 0 |
| Estimated not meeting or moving toward FPMO | 0 | 23 | 23 |
| Total | 1 (0%) | 23 (7%) | 23 (7%) |
| Undetermined status | 276 | 265 | 265 |

face or sub-surface water, these areas often exhibit faster recovery rates from the effects of improper management (Alford 1993, Hindley 1996, Mosley et al. 1997). Additionally, the strategic goals of the Forest Service, NRCS, and the BLM include specific objectives designed to restore and maintain watershed function and structure in order to reduce erosion and improve water quality. The overall goals of the Clean Water Act are further supported by the interagency responsibilities outlined in the Clean Water Action Plan (CWAP), announced by the President on February 19, 1998. The CWAP contains key action items for federal agencies and provides for incentives relative to private land stewardship.

Some reviewers conclude that grazing by domestic livestock is not compatible with restoring watersheds and water quality, at least in the short term (Belsky et al. 1999). However, comparitive research and case studies show that improved rangeland and livestock management practices are compatible with watershed and water quality improvement when designed to address the attri-

**Table 3.24—**Area of riparian range vegetation within grazing allotments on National Forest System lands in relation to Forest Plan Management Objectives (FPMO): North Assessment Region (acres  $10^2$).

| Land Category | Year 1995 | 1996 | 1997 |
|---|---|---|---|
| Having range vegetation management objectives | 17 | 17 | 1 |
| Monitored during current year | 12 | 12 | 1 |
| Verified meeting FPMO | 2 | 2 1 | |
| Estimated meeting FPMO | 2 | 2 | 0 |
| Total | 4 (29%) | 4 (29%) | 1 (100%) |
| Verified moving toward FPMO | 1 | 1 | 0 |
| Estimated moving toward FPMO | 6 | 6 | 0 |
| Total | 7 (50%) | 7 (50%) | 0 (0%) |
| Verified not meeting or moving toward FPMO | 1 | 1 | 0 |
| Estimated not meeting or moving toward FPMO | 2 | 2 | 0 |
| Total | 3 (21%) | 3 (21%) | 0 (0%) |
| Undetermined status | 3 | 3 | 0 |

butes of each individual site (Elmore and Kauffman 1994). Ultimately, social and political values, along with scientific knowledge, will drive future laws and regulations affecting the grazing use of riparian areas, just as they will for uplands (Lee 1993).

## Lands Managed by Department of Defense

The Department of Defense (DOD) is responsible for administering more than 25 million acres of federal land in the United States (Public Land Law Review Commission 1970). In addition to these lands, DOD services have agreements with states and other federal land managment agencies, including the Forest Service, to allow training use on 15 million additional acres (Council on Environmental Quality 1989). The U.S. Army Corps of Engineers manages 12 million acres of this land through its civil works programs.

Military commanders responsible for DOD lands must address two important national goals: maintaining military readiness and safeguarding the environment. The emphasis on environmental stewardship began with a 1989 challenge by Secretary Cheney for DOD to be "the federal leader in environmental compliance and protection" (Baca 1992). On the other hand, military readiness increasingly requires large-unit, mechanized exercises that reduce vegetation cover and soil stability, and destroy woody vegetation (Siehl 1991). Consequently, the military has become more and more involved in land management and land restoration concurrently with the execution of its training activities (Berlinger and Cammack 1990). Conservation has been incorporated into training guidelines at all installations (Shaw and Diersing 1989). Protection of plant and animal species for biodiversity is receiving increased consideration in military land management planning (Vogel 1997).

In the mid-1980's the U.S. Army initiated a service-wide ecosystem monitoring program called Land Condition-Trend Analysis (Diersing et al. 1992). The procedures adopted are described in a Corps of Engineers technical manual (Tazik et al. 1992). Although the base sampling protocols are the same worldwide, the amount of information synthesized across a regional or national scale is still limited. This situation is expected to improve greatly over the next few years through improved data analysis and synthesis activities, and collaboration with other land management agencies (Mitchell and Shaw 1993).

A recent report provides an approximation of ecosystem health for training lands in the continental United States administered by DOD (Shaw and Kowalski 1996). The authors surveyed 32 military installations, half of which were dominated by desert, grassland, shrubland, or woodland vegetation. The land area of the 16 installations characterized by rangeland ecosystems was 7.1 million acres. About 20 percent of all rangeland showed evidence of livestock use. The principal disturbances on military lands were related to human activities, however. Approximately 17 percent of all lands, including forests, was disturbed because of military operations. Sixty percent of this land area showed signs of accelerated erosion. Evidence of fires could be found on almost two-thirds of the land, often because of use of munitions and other incendiary devices (Shaw and Kowalski 1996).

# Expansion of Woodlands

Trees and shrubs are found on rangelands worldwide. Nonetheless, native woody plants have rapidly increased in abundance on a number of arid and semi-arid grassland steppes and savannas over the past century, clearly expanding beyond their historical range of distribution in the United States (Archer 1994). The area of these expanded woodland types, as well as the increased soil erosion that can accompany such land cover shifts, are indicators of sustainability under the Montreal Process (USDA Forest Service 1997).

Ecologists first noticed the invasion of grasslands by woodland species early in the 20th Century (Foster 1917, Leopold 1924). By mid-century, numerous scientific articles addressed the issue of increasing extent and/or density of mesquite (*Prosopis glandulosa*) (Allred 1949, Brown 1950), creosote bush (*Larrea tridentata*) (Gardner 1951), and juniper (*Juniperus* spp.) (Johnson 1962, Burkhardt and Tisdale 1969). Oak brush (*Quercus gambelii*) was noted to thicken, if not spread, under disturbance by fire or cutting (Brown 1958). At that time, Platt (1959) estimated that these woody species occupied the following area:

| Species | Area (acres $10^6$) |
|---|---|
| Mesquite | 93.0 |
| Creosote bush | 46.5 |
| Juniper | 63.9 |
| Oak brush | 40.2 |

The causes of woodland expansion, and the resultant balance between the distributions of grasslands and woody plant communities, are complex and interactive. They comprise changing climate, including episodic events, grazing, and fire (Archer et al. 1999). Grover and Musick (1990) concluded that the extensive expansion of mesquite and creosote bush in the Southwest was brought about by livestock overgrazing in the late 19th Century that coincided with drought conditions unfavorable for perennial grass growth. Evidence is beginning to suggest that droughts and global warming may favor forbs and some woody species over grasses in parts of North America (Turner 1990, Paruelo and Lauenroth 1996, Alward et al. 1999).

Non-equilibrium successional models with a critical threshold between the grassland domain and woodland/shrubland domain also provide a mechanism for explaining dynamic interactions between grasslands and woodlands (Archer and Smeins 1991). Increased grazing and decreased fire frequency can drive succession towards a woodland state (figure 3.2). If grazing pressure is

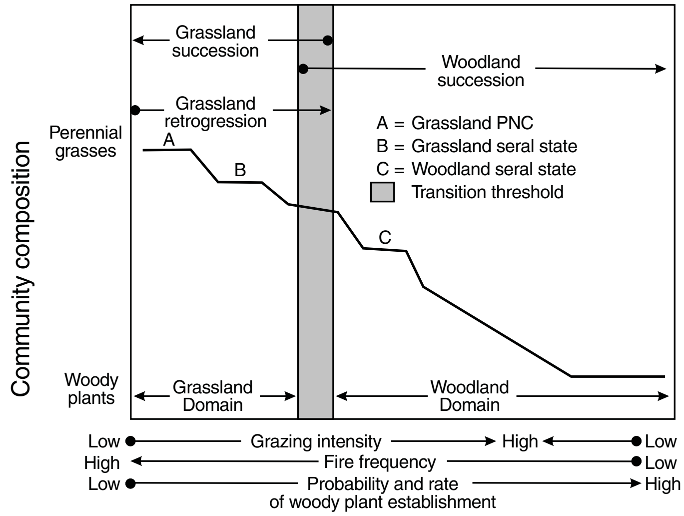



**Fig. 3.2**—Conceptual model of how grazing and fire interact to convert a grassland to a shrub-dominated ecosystem. The threshold is determined by the establishment of shrub-driven successional processes once shrub dominance reaches a critical level (adapted from Archer 1989).

relaxed prior to reaching some critical threshold, succession towards a later seral grassland can occur; otherwise, the transition can be permanent (Archer 1989).

Most research evidence indicates that two of the major anthropocentric disturbance factors, livestock grazing and fire, had their controlling impacts in the late 19th and early 20th centuries—the time shortly before woodland expansions were being documented (Buffington and Herbel 1965, Baisan and Swetnam 1997). An additional factor, non-indigenous plants, has continued to deleteriously affect woodlands by forming closed, mono-specific understories that decrease biodiversity (Young and Longland 1996) and promote accelerated erosion (West 1991b).

A number of management techniques have been devised over the past half-century to reduce or eliminate tree dominance in woodlands. Fire has seldom worked in pinyon-juniper because of a lack of fine fuels, often caused by grazing, to carry a fire (Miller et al. 1994). Treatments other than fire, such as cabling and chaining, were first designed to increase forage production for livestock and harvest firewood. The management emphasis for treating woodlands in recent years has been to enhance wildlife habitat. Wildlife treatments have generally been less frequent and tended to involve smaller areas than natural wildfires, allowing trees to more rapidly reoccupy their former territories. Some treatments have included seeding of introduced grasses and forbs that replaced native species, detrimentally impacting biodiversity (Richards et al. 1998).

Although most scientific literature supports the premise that controlling pinyon-juniper in areas outside its

**Table 3.25—**Area of non-federal rangelands for selected woody species, by cover class, for selected states, in 1992 (acres 10³).

| | Total Woody Cover (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| Region/Species | <1 | 1–9 | 9–20 | 20–30 | 30–40 | >40 | Total |
| **Pacific Coast Assessment Region** | | | | | | | |
| California | | | | | | | |
| Pinyon-Juniper | 0 | 65 | 254 | 241 | 0 | 81 | 641 |
| Creosote bush | 0 | 66 | 261 | 265 | 265 | 643 | 1,500 |
| Oregon | | | | | | | |
| Juniper | 295 | 636 | 651 | 314 | 147 | 89 | 2,312 |
| **Rocky Mountains Assessment Region** | | | | | | | |
| Arizona | | | | | | | |
| Pinyon-Juniper | 695 | 3,593 | 1,220 | 517 | 210 | 53 | 6,288 |
| Creosote bush | 222 | 1,923 | 2,199 | 894 | 299 | 0 | 5,537 |
| Mesquite | 0 | 104 | 57 | 57 | 57 | 229 | 514 |
| Colorado | | | | | | | |
| Pinyon-Juniper | 187 | 760 | 376 | 0 | 31 | 31 | 1,385 |
| Idaho | | | | | | | |
| Juniper | 0 | 0 | 87 | 14 | 0 | 0 | 101 |
| Nevada | | | | | | | |
| Pinyon-Juniper | 26 | 270 | 237 | 18 | 18 | 0 | 569 |
| Creosote bush | 0 | 103 | 137 | 0 | 0 | 0 | 240 |
| New Mexico | | | | | | | |
| Pinyon-Juniper | 583 | 7,048 | 4,478 | 765 | 368 | 21 | 13,283 |
| Creosote bush | 73 | 1,001 | 601 | 140 | 74 | 1 | 1,890 |
| Mesquite | 941 | 4,213 | 2,258 | 756 | 140 | 81 | 8,389 |
| Utah | | | | | | | |
| Pinyon-Juniper | 77 | 852 | 367 | 98 | 95 | 0 | 1,489 |
| **Southern Assessment Region** | | | | | | | |
| Oklahoma | | | | | | | |
| Mesquite | 68 | 477 | 151 | 0 | 0 | 0 | 696 |
| Texas | | | | | | | |
| Juniper | 1,424 | 8,620 | 5,289 | 1,823 | 1,002 | 1,702 | 19,860 |
| Creosote bush | 780 | 3,657 | 2,706 | 616 | 118 | 127 | 8,004 |
| Mesquite | 4,067 | 20,032 | 14,349 | 4,782 | 2,054 | 2,143 | 47,430 |

recent historical range reduces erosion and increases soil water and understory abundance, this conclusion is not unanimous (Belsky 1996).

Woody cover of mesquite, creosote bush, and juniper on non-federal rangelands in the PC, RM, and SO Assessment Regions is presented in table 3.25 (from unpublished 1992 supplemental NRI study, described earlier in the section on non-federal rangeland health). Although the total acreages cannot be compared with Platt's (1959) estimates, the 1992 data do provide an interesting perspective on cover class distributions for non-federal lands. In general, the areas dominated by woody species are characterized by communities with less than 20 percent canopy cover. It should be noted that non-federal lands occupy less than one-fourth of all lands in the two principal pinyon-juniper states of the Great Basin, Nevada and Utah (USDA Soil Conservation Service 1990). Further, private lands in the Great Basin are situated primarily at lower elevations and do not include many productive sites (West et al. 1978). Research has shown that woodlands have greater canopy cover at higher elevations in the Great Basin, and that the median cover for all sites is on the order of 45–50 percent (figure 3.3) (Tausch and Tueller 1990, West et al. 1998).

The increased distribution, density, and crown size of pinyon-juniper on more favorable sites typical of federal lands have amplified the risk of large crown fires that have the potential to burn over large areas. The area of

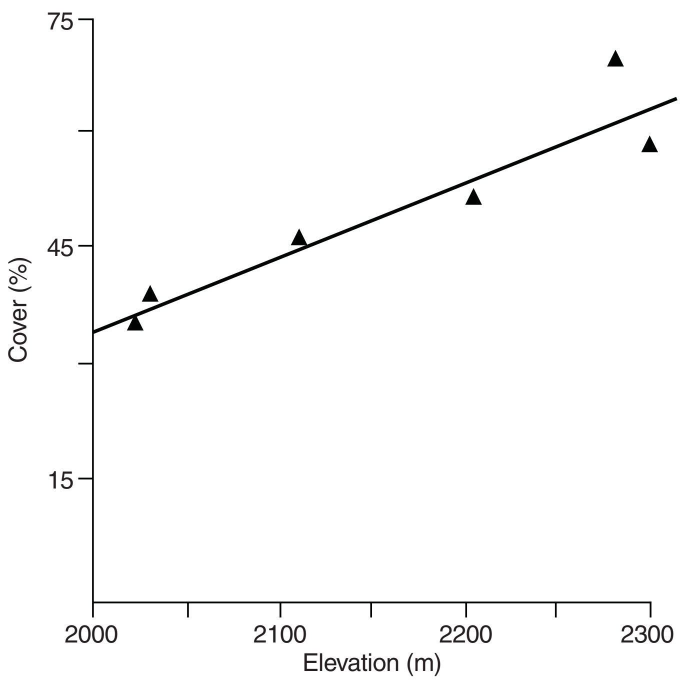



**Fig. 3.3**—Relationship between elevation and percent cover in tree-dominated pinyon-juniper woodlands. Adapted from Tausch and Tueller (1990).

mature woodlands is currently expanding faster than it is being lost from wildfire, but this net trend shows signs of reversal (Tausch 1999a). Nationally, woodlands seem to be expanding at a decreasing rate, however. For example, the extent of pinyon-juniper ecosystems in the western United States is estimated to be 56 million acres (Mitchell and Roberts 1999), no more than inferred by Platt (1959) 40 years ago. Pressures to control woodland trees over the next 50 years may shift to a strategy of restoring patch size distributions instead of controlling future expansions.

## Decline of Quaking Aspen

Quaking aspen (*Populus tremuloides*) stands have long been valued both for wildlife habitat and as a regionally important source of summer livestock forage (Ellison and Houston 1958). Forage biomass in some aspen stands can exceed 4,000 lb./ac. Species diversity indices of both plants (Houston 1954) and animals (Smith and MacMahon 1981) are relatively high in aspen communities, particularly when compared to surrounding coniferous communities. Quaking aspen has been cited as an excellent indicator of ecosystem integrity because the species does not establish from seed (Kay 1997).

Landscapes dominated by quaking aspen receive exceptionally high recreational use during early fall when the trees' leaves turn a brilliant gold. Tours, festivals, and other activities highlighting aspen may be found throughout the Rocky Mountains from mid-September to mid-October each year. Although the scenic value of aspen communities may now exceed commercial uses, very little research has been conducted to assess its aesthetics (Johnson et al. 1985).

The quaking aspen type extends from eastern Canada to Alaska, and southward to Mexico in the western United States (Jones 1985). Mueggler (1985) has summarized aspen-dominated vegetation associations in the Northern, Central, and Southern Rocky Mountains, Colorado Plateau, Black Hills, Northern Great Plains, and Sierra Nevada Mountains. The largest clones and most extensive distribution of aspen are in the Colorado Plateau states of Utah and Colorado. In the early 1980's, quaking aspen occupied 7.1 million acres in the RM Assessment Region (Green and Van Hooser 1983).

Aspen reproduction is unique from other montane trees in that it sprouts vegetatively from a persistent parent root system. Such reproduction can only be triggered by disturbance, primarily fire. Most aspen communities are considered seral, and will slowly be replaced by conifers or sagebrush/grass with a lack of disturbance. Thus, recurring fires have maintained the abundance of aspen in the western United States, even though the transition to a different community-type can take more than 500 years (Jones and DeByle 1985).

Historical research has confirmed that fire frequency has greatly decreased in aspen in the same manner it has within other western forest and woodland zones since the mid 19th Century (Baker 1925, Bartos and Campbell 1998). As the interval between fires lengthens, aspen is more prone to be eliminated from the landscape because the competitive edge of vegetative over sexual reproduction is forfeited in the absence of periodic disturbance (Noble and Slatyer 1980). Aspen stands are not easily burned, so continued overgrazing by domestic livestock, deer, and elk can exacerbate the lack of fire by reducing fine fuels (Jones and DeByle 1985). In addition, browsing of suckers by livestock and wildlife can directly thwart regeneration of quaking aspen (Kay 1997, Suzuki et al. 1999).

As a consequence of past domestic grazing practices, expanding populations of elk and deer, and a long-term strategy of quickly fighting all forest fires, the abundance of quaking aspen has dramatically declined in the last century. Bartos and Campbell (1998), using Forest Inventory and Analysis (FIA; Rocky Mountain Research Station, 507-25th St., Ogden, UT 84401) data on size and distribution of existing stands, estimated that quaking aspen has declined by 60 percent to a present area of 800,000 acres on NFS lands in Utah. O'Brien (1999) reported aspen declined from 2.9 million acres to 1.4 million acres on all lands in Utah, a loss of slightly more than 50 percent.

Historical estimates of quaking aspen abundance were obtained by FIA following an algorithm with the following assumptions: Aspen clones cannot regenerate once the parent root system dies; one or more aspen stumps or logs denote a former clone; and the size of aspen clones has not significantly changed over the past several hundred years. As a result, the historical area occupied by quaking aspen can be estimated by concluding that each location where stumps or logs of dead aspen are found supported an average-sized aspen clone. Based upon FIA data provided by D.L. Bartos (Rocky Mountain Research Station, 860 N. 12th East, Logan, UT 84321) and this algorithm, we estimate that west-wide, quaking aspen has declined by 60 percent since settlement by Europeans (table 3.26).

Whether the downward trend in quaking aspen abundance can be reversed will depend upon proper livestock grazing plans, the ability to control excessive browsing by wildlife, and our ability to restore natural regeneration using silvicultural techniques such as clearcutting, fire, and the use of herbicides (Schier et al. 1985). With declining public support for clearcutting and the use of chemicals, increasing populations of deer and elk (Flather et al. 1999), and the high cost of prescribed fire in forested ecosystems, there is no reason to expect the rate of aspen decline to markedly change over the next 50 years.

**Table 3.26—**Decline in area of quaking aspen (*Populus tremuloides*) in eight Rocky Mountains Assessment Region states from historical levels in the mid-19th Century.

| | Area Occupied (acres 10³) | | |
|---|---|---|---|
| State | Historical Area | Current | Decline (%) |
| Arizona | 721 | 29 | 96 |
| Colorado | 2,188 | 1,111 | 49 |
| Idaho | 1,610 | 622 | 61 |
| Montana | 591 | 211 | 64 |
| Nevada | N/A | 119 | — |
| New Mexico | 1,142 | 140 | 88 |
| Utah | 2,931 | 1,428 | 51 |
| Wyoming | 436 | 204 | 53 |
| Total[1] | 9,619 | 3,745 | 61 |

*N/A = Not available.*

[1] *Not including Nevada*

Source: D.L. Bartos, Rocky Mountain Research Station, Logan, UT. Data are originally from the Forest Inventory and Analysis Work Unit, Rocky Mountain Research Station, Ogden, UT.

## Non-Indigenous Plants

The spread of plant and animal species outside their historic home ranges constitutes an important indicator of forest and rangeland ecosystem health and vitality (USDA Forest Service 1997). On a global scale, biological invasions of non-indigenous species not only are disrupting natural ecosystems, but are to a greater and greater degree threatening human health and burdening economies (Vitousek et al. 1996). The invasion of non-native plants onto forests and rangelands has been likened to wildfires wherein entire areas have been made useless in a comparatively short period of time, requiring the same form of open-ended funding to control (Westbrooks 1998). Bright (1998) declared bioinvasions to be a form of evolution-in-reverse because human activities have negated the effectiveness of barriers isolating thousands of particular ecosystems around the world.

Exotic or non-indigenous plants are species that have been introduced into ecosystems in which they did not evolve, and, consequently, tend to have no natural enemies to limit their reproduction and expansion. Where introduced, they tend to be more vigorous and taller, producing more seeds, than in their native environment (Crawley 1987). Invasive plants fall largely under the ruderal and competitive life history strategies proposed by Grime (1977); ruderal where weeds appear after disturbance, and competitive where they are better adapted to conditions of low stress and low disturbance. Noble (1989) identified two strategies for invading habitats where native species are displaced: where the invader is a superior competitor, and where the invader has characteristics permitting it to survive under unique conditions such as extreme events.

Alien plants have both environmental and economic consequences to those managing rangelands. They displace native species, even those firmly established, and alter ecosystems principally through stand renewal and successional processes (Young and Longland 1996). Exotic species are invasive in that they can spread quickly, even though the ecosystem may be in good ecological condition (Tyser and Key 1988), although conclusive evidence supports the premise that disturbance almost always has some role in promoting biological invasions (Rejmánek 1989). All things considered, perhaps every rangeland ecosystem has been disturbed to some degree (Pickett and White 1985).

Non-indigenous plants have been shown to hybridize with native species, an insidious process that lessens the distinction between alien and non-alien species (Abbott 1992). Hybridization may become especially destructive in designated wildernesses and other protected areas (Cole and Landres 1996).

From a legal point of view, noxious weeds are different from non-indigenous plants. The former consist of species that are officially listed by a state or county, usually under the purview of state law, for the purpose of their control. Species on noxious weeds lists are usually non-indigenous, but not always. This section deals with non-indigenous invasive plants.

The prevalence of invasive non-native plants on U.S. grazing lands became broadly understood in the early 1990's with the publication of a comprehensive report by the U.S. Congress, Office of Technology Assessment (1993). By 1998, 17 federal agencies reached an understanding to form the Federal Interagency Committee for Management of Noxious and Exotic Weeds (1998). The Committee was established to develop an integrated ecological program to manage noxious and exotic weeds on federal lands, and provide technical assistance to private landowners (Westbrooks 1998). On 3 February 1999, President Clinton issued an executive order establishing a cabinet-level Invasive Species Council to provide national leadership in controlling and managing invasive species.

Land managers now rank weeds among their most burdensome problems; more than 1 in 10 stewards of lands owned by The Nature Conservancy have identified weeds as their worst management problem (Randall 1996).

The ratio of non-native species to all flora varies globally by region from 1 percent in the Mediterranean region to nearly 50 percent in New Zealand (Quezal et al. 1990, Heywood 1989). Regions dominated by deserts and savannas are less influenced than more mesic regions, as is the eastern hemisphere in comparison to the western hemisphere. Within continents, the degree of invasion rises with latitude (Lonsdale 1999). There is conflicting evidence concerning the positive vs. negative relationship between invasibility and biodiversity (Tilman 1997, Lonsdale 1999), although the differences may be related to scale. Stohlgren et al. (1999) concluded that exotic species are more likely to invade areas of high species richness at the landscape and biome levels because both biodiversity and invasibility are positively correlated with resource richness.

Canada and the United States each have about 2,000 non-indigenous invasive plant species, although within the United States these species are concentrated in three states—California, Florida, and Hawaii (U.S. Congress, Office of Technology Assessment 1993). According to one review, non-indigenous plants comprise 14 percent of all species in the Great Plains (Rejmánek and Randall 1994). Even though much of the mid- and tall-grass prairies have been planted to agronomic crops for many years, it is not unreasonable to expect associated grasslands to have a similar percentage of alien species.

Non-indigenous weeds are rapidly escalating on U.S. rangelands. During the 19th Century, 90 to 120 new species were introduced per decade in the Pacific Northwest. The decennial rate of new non-indigenous species declined to as low as 30 species during the 1930's and 1940's, however, before closing in on the previous frequency of introductions in the mid-20th Century (figure 3.4). Expanding global commerce and travel are certainly the major causes of the recent expansion. Interestingly, the first surge of invasive plant species tended to be annuals, while greater proportions of perennials, including woody plants, characterize species introductions during the latter 20th Century (Toney et al. 1998).

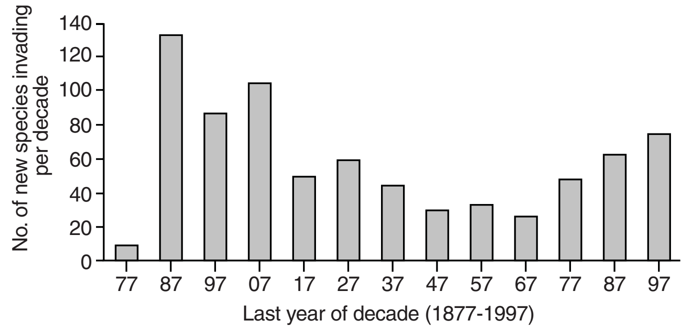



**Fig. 3.4**—Invasion of non-indigenous weeds, by decade, in Washington, Oregon, Idaho, Montana and Wyoming. Unpublished data from testimony of Peter M. Rice, University of Montana, to the Senate Agriculture Committee, 8 May 1999, Nampa, ID.

The USDI Bureau of Land Management (1996a) Action Plan alluded to information showing that weeds have seriously infested 8.5 million acres, or 5 percent, of BLM lands. However, they estimated the area impacted to be increasing at a rate of 2,300 acres/day, an amount that would bring the area of BLM lands infested to approximately 19 million acres by the year 2000. The same reference predicted an infestation rate for all public lands in the West to be double that found on BLM lands—4,600 acres/day—leading to a total wildland infestation of 33 million acres by the year 2000.

Although there is little doubt that invasive weeds have been increasing in abundance across U.S. grazing lands, no sources of data exist that can be agglomerated to estimate the total magnitude of infestation. Information from both published and unpublished sources is summarized by species below. Still, one can logically surmise that the gravity of the present non–indigenous rangeland weed situation cannot be adequately characterized by aggregating material that is neither current nor collectively exhaustive.

## Leafy Spurge

Leafy spurge (*Euphorbia esula*) is a deep-rooted perennial forb with milky sap that forms expansive dense patches. It is difficult to control because of its extensive root system and its ability to spread by seed. The species has spread widely, from coast to coast across the northern United States over the past 80 years. Twenty years ago, leafy

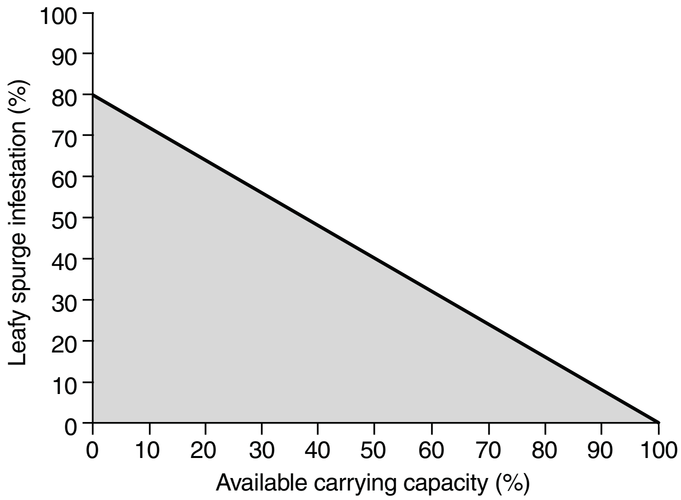



**Fig. 3.5**—Relationship between leafy spurge infestation and rangeland livestock carrying capacity. Adapted from Leistritz et al. (1993).

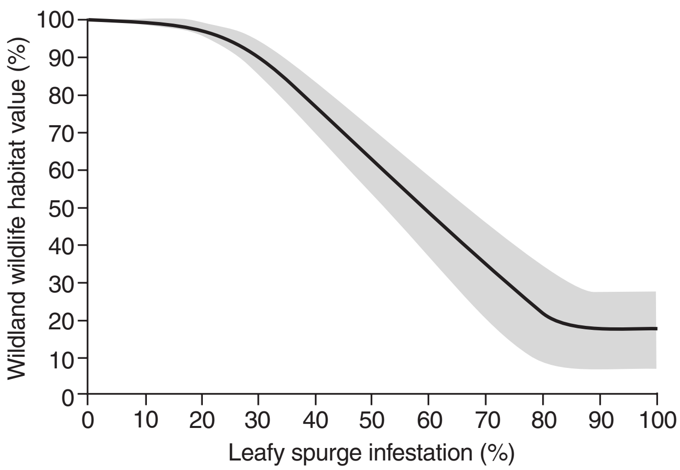



**Fig. 3.6**—Relationship between leafy spurge infestation and wildlife habitat value. Adapted from Leistritz et al. (1993).

spurge was reported in 458 counties in 26 states (Dunn 1979). The species expanded in a linear fashion into new counties in Montana and surrounding states until the mid-1980's, after which it mushroomed exponentially (unpublished data from the Invaders data base; see <http://invader.dbs.umt.edu>). Lym (1991) applied data in Dunn's paper to estimate the extent of leafy spurge in the Northern Great Plains, including Canada, at 2.7 million acres.

Leafy spurge, like other alien invasive weeds, costs rangeland owners and managers directly through decreased grazing capacity (figure 3.5) and wildlife habitat (figure 3.6). Weeds also generate secondary costs through lost jobs and reduced spending by visitors. The direct and

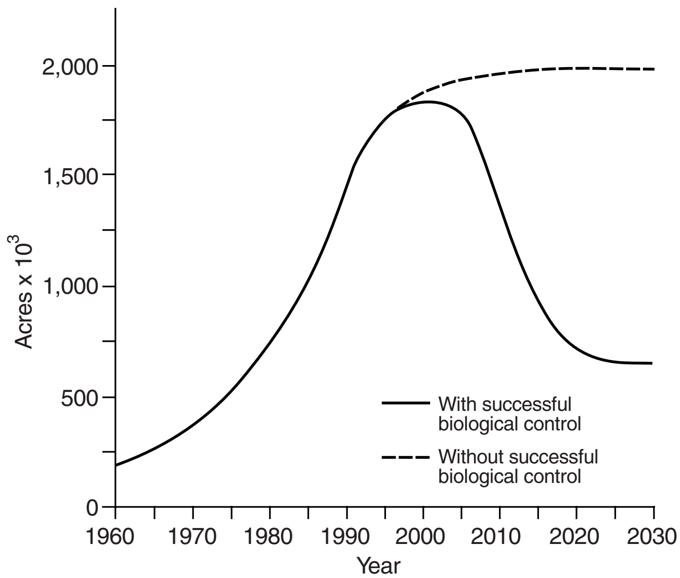



**Fig. 3.7**—Historic and projected extent of leafy spurge infestations in the Northern Great Plains. Adapted from Bangsund et al. (1999).

secondary economic impacts of leafy spurge in the Upper Midwest, alone, were estimated to be $120 million in 1993 (Leitch et al. 1996).

Regardless of the exponential increase in leafy spurge over the latter half of the 20th Century, some experts expect the rate of growth will slow and even decrease over the next 30 years in the Northern Plains because the species has already occupied much of the areas in which it is best adapted (figure 3.7). The actual future expanse of leafy spurge will depend, as with other invasive plants, upon the success of biological control measures (Bangsund et al. 1999).

## Knapweeds and Starthistles

About 15 species of knapweeds and starthistles (*Centaurea* spp.) have invaded U.S. rangelands. The genus originated in the Mediterranean region. Among the most significant invaders are spotted knapweed (*C. maculosa*), diffuse knapweed (*C. diffusa*), Russian knapweed (*C. repens*), and yellow starthistle (*C. solstitialis*). As a group, these species are deemed as being harmful to rangelands because they often invade communities that are in relatively good condition, cause sites to be more erodible, and provide little forage or wildlife habitat value (Lacey et al. 1989, Roché and Roché 1991).

*Centaurea* spp. have replaced native species on millions of acres of rangeland in western North America (Lacey and Olson 1991). The four species listed above occupy at least 20 million acres by themselves (table 3.27). The eco-

**Table 3.27—**Area occupied by four non-indigenous noxious species of *Centaurea* in the western United States. From Lacey and Olson (1991).

| Common name | Species | Area occupied (acres $10^6$) |
|---|---|---|
| Spotted knapweed | *C. maculosa* | 7.3 |
| Diffuse knapweed | *C. diffusa* | 3.2 |
| Russian knapweed | *C. repens* | 1.4 |
| Yellow starthistle | *C. solstitialis* | 9.4 |

nomic impact of knapweeds and yellow starthistle upon rangeland is severe, especially where they have taken over productive sites. In Montana alone, losses in forage value amounted to more than $10.50 per infested acre in 1994. Total economic costs in Montana, including those associated with grazing, wildlife habitat, and soil and water conservation, were estimated at $14.1 million annually during the same year (Hirsch and Leitch 1996).

Knapweeds and yellow starthistle are primarily controlled with chemicals (Sheley and Jacobs 1997), but chemical control is only cost-effective on productive sites where increased forage production can adequately compensate for the cost of treatment (Griffith and Lacey 1989). Integrated control measures, involving biological agents, grazing, fire, and chemicals, are seen as a more long-term solution to the problem (Hrubovcak et al. 1999). Although phytophagous insects to control knapweed were introduced as far back as the 1970's (Müller et al. 1988), research has shown that the introduction of natural enemies alone does not commonly reduce *Centaurea* spp. dominance, and can even decrease the competitive ability of associated native plants (Callaway et al. 1999).

No quantitative approaches are available to project the spread of *Centaurea* spp. in the United States. Chicoine et al. (1985) estimated spotted knapweed was expanding at an approximate rate of 25 percent per year in Montana, and that the species had the potential to increase from 2 million acres at the time of their work to 35 million acres. The real uncertainty with *Centaurea* spp., as with other non-indigenous plants, lies with understanding how far and to what extent they will spread beyond the ranges in which they are found now.

## Saltcedar

Saltcedar (*Tamarix* spp.), an aggressive phreatophyte, was first introduced into the United States as an ornamental in the early 19th Century (Horton 1964), but has been a robust invader of riverine and riparian rangeland ecosystems during the past 60 years (Busby and Schuster 1971, Di Tomaso 1998). In the Southwest, particularly,

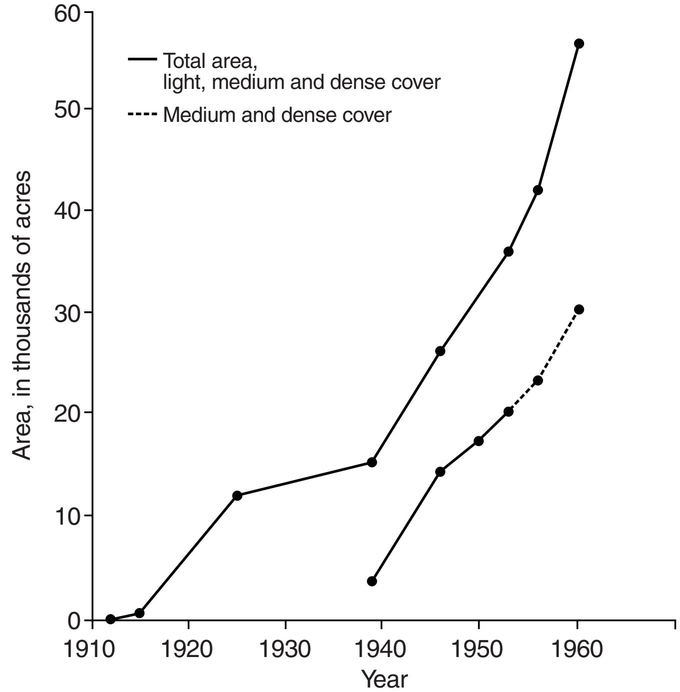



**Fig. 3.8—**Expansion of saltcedar along a 200-mile reach of the Pecos River in southeastern New Mexico. Adapted from Robinson (1965).

saltcedar has replaced more benign native phreatophytes such as cottonwoods and willows (Busch and Smith 1995). In some areas, water management practices and dam construction have dropped floodplain water tables and stopped recurring scouring of river banks, thus further reducing the competitiveness of native woody species (Howe and Knopf 1991). With its extremely high transpiration rate and capability for osmotic adjustment, saltcedar, once established, can depress the water table by itself, giving the species an added competitive advantage over native phreatophytes because of its higher water use efficiency (Davenport et al. 1982, Busch and Smith 1995). Robinson (1965) calculated that a dense 1-acre stand of saltcedar is capable of transpiring 11,100 $m^3$ (9 acre-feet) of water annually.

The present extent of saltcedar is not precisely known. More than 30 years ago, Robinson (1965) showed *Tamarix* spp. to be established in every conterminous state west of the 95th Meridian except North Dakota, Idaho, and Washington, occupying 1.5 million acres. Like other rangeland weeds, saltcedar has expanded exponentially within some parts of its range (figure 3.8). It now is found along the main branches and tributaries of the Snake and Columbia Rivers in Idaho and Washington (unpublished data from the Invaders data base), as well as in North Dakota (unpublished data from the PLANTS data base, see <http://plants.usda.gov/plantproj/plants/index.html>).

Controlling saltcedar will not be an easy task. U.S. Congress, Office of Technology Assessment (1993) cited a Bureau of Reclamation report estimating the cost of restoring native phreatophytes to the lower Colorado River to be as much as $450 million. The species is resistant to herbicides and root-plowing because of its ability to sprout following treatment (Kerpez and Smith 1987).

## Non-Indigenous Thistles

Thistles are somewhat of an anomaly. While the majority of thistles are native to the United States, occurring inconspicuously from low to mid-montane elevations across wide regions, a few introduced Eurasian species are among the most deleterious of weeds on western rangelands (Dewey 1991). Canada thistle (*Cirsium arvense*) has been declared a noxious weed in at least 35 states from California to Maine and Washington to Georgia. Musk thistle (*Carduus nutans*) has been so designated in half as many states in every U.S. region except the Southeast. A third thistle, Scotch thistle (*Onopordum acanthium*) is a major invader of rangelands in the PC Assessment Region. Invasive thistles are biennials or short-lived perennials.

No one knows the extent of alien thistle populations on U.S. rangelands. In montane regions, Canadian thistle can dominate the understory after logging, but lose out to native species after a few years. Whether or not such areas of transient dominance should qualify in assessing the health of grazing lands is unclear. In other areas, thistles persist for years after disturbance.

Colleagues at the Department of Bioagricultural Sciences and Pest Management, Colorado State University, and I conducted a survey of state weeds specialists in 1997. With reference to Canadian thistle, we received estimates from seven RM Assessment states (ID, KS, ND, NE, SD, UT, WY), five states in the NO Assessment Region (DE, MN, NH, NJ, PA) and two states in the SO Assessment Region (FL, LA). The specialists conjectured that a total of 3.0 million acres of Canadian thistle could be found in their states, which collectively comprise 27 percent of the land mass of the conterminous 48 states. The invaded area equaled 0.6 percent of the area of these 14 states, ranging from <.01 percent in Kansas and Wyoming to 4 percent in Delaware and Pennsylvania (May 1999). Even if the above estimates exceeded actual infestations by a factor of two, extrapolation implies that Canada thistle would still occupy nearly 6 million acres in the conterminous United States.

## Purple Loosestrife

Although wetlands, marshy sites, and riparian zones comprise a small part of rangeland landscapes in the United States, their sustainability is essential for the maintenance of biodiversity, clean water supplies, wildlife habitat, recreational opportunities, and as a forage supply for both wild and domestic grazing animals. Purple loosestrife (*Lythrum salicaria*), a colorful, tall perennial herb from Europe, has invaded wetlands in nearly every U.S. region and Canada, particularly across the northern tier of states. It is listed as a noxious weed in 24 states (Westbrooks 1998). The species has expanded rapidly westward since the early 1940's, but new infestations have been most remarkable in western states from California to Montana (Thompson et al. 1987).

Once established, purple loosestrife forms dense, monotypic stands that decimate biodiversity, wildlife habitat, and forage value (Malecki et al. 1993). It is highly competitive in multiple environments, fertile vs. unfertile, drained vs. flooded (Keddy et al. 1994). The weed's ability to invade infertile habitats is particularly detrimental for threatened and endangered wetland plants because of the propensity of rare plants to occupy such sites (Moore et al. 1989).

Purple loosestrife reduces U.S. forage supplies in two ways: by replacing palatable graminoid and forb species in wet meadows that are grazed or hayed, and by clogging irrigation ditches that deliver water to forage-producing land (Mullin 1998). No actual data delineate the area of wetlands infested or biomass of forage lost because of purple loosestrife.

## Cheatgrass

Cheatgrass (*Bromus tectorum*) is a winter annual grass that invaded from the Mediterranean region in the mid-19$^{th}$ Century (Klemmedson and Smith 1964). It is now widely distributed throughout North America, where it occurs in every U.S. state, Canada, and Mexico (Westbrooks 1998). Mack (1981) has suggested that cheatgrass is universally present on 100 million acres of steppe vegetation within the RM and PC Assessment Regions alone. Cheatgrass is so ubiquitous that, more than any other species, it may have fostered the concept of PNC as a replacement for climax in successional theory (figure 3.9). Aldo Leopold (1949) captured the idea of cheatgrass' unpretentious, yet total, occupation of rangelands in an essay called "Cheat Takes Over" when he stated that "one simply woke up one fine spring to find the range dominated by a new weed."

The abundance of cheatgrass has caused some livestock producers to use it as a source of early spring forage. Cheatgrass provides a balanced ration in early spring before perennial grasses commence growth (Cook and Harris 1952). The disadvantage of grazing cheatgrass lies in its extreme fluctuations in production from year to year. Nonetheless, the species is unique among non-

**Table 3.28—**List of non-indigenous weed species not described in document text.

| Common Name | Scientific Name | Distribution | Reference |
|---|---|---|---|
| Medusa head | *Taeniatherum aspeum* | PC, RM | Hilken and Miller 1980 |
| Perennial Pepperweed | *Lepidium latifolium* | PC, NO, SO | Young et al. 1998 |
| Mediterranean sage | *Salvia aethiopis* | PC, RM | Roché and Wilson 1999 |
| Russian olive | *Elaeagnus umbellata* | U.S. | Olson and Knopf 1986 |
| Dalmatian toadflax | *Linaria dalmatica* | PC, RM | Alex 1962 |
| Yellow toadflax | *Linaria vulgaris* | PC, RM | Saner 1994 |
| Whitetop | *Cardaria pubescens* | PC, RM, NO | Sheley and Stivers 1999 |
| Rush Skeletonweed | *Chondrilla juncea* | PC, RM | Heap 1993 |
| Oxeye daisy | *Chrysanthemum leucanthemum* | PC, RM, NO | Olson and Wallander 1999 |
| Hounds tongue | *Cynoglossum officinale* | PC, RM | Upadhyaya et al. 1988 |
| Tanzy ragwort | *Senecio jacobaea* | PC, RM | McEvoy et al. 1991 |
| Kudzu | *Pueraria lobata* | SO, NO | Miller and Edwards 1982 |
| Mile-a-minute | *Polygonum perfoliatum* | SO, NO | McCormick and Hartwig 1995 |

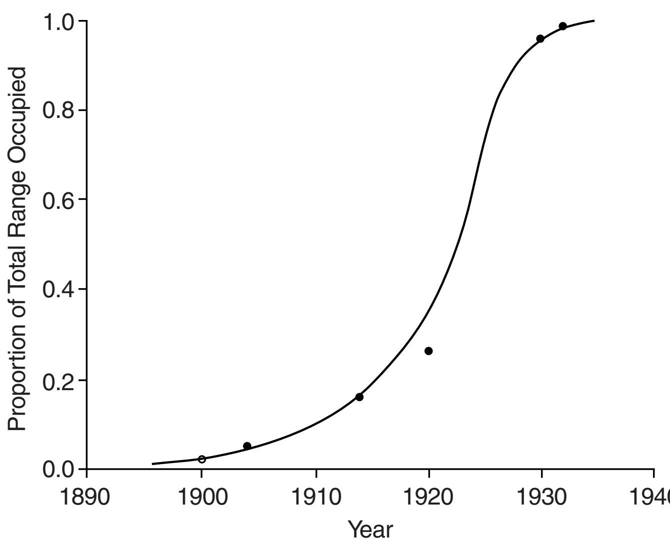



**Fig. 3.9—**Expansion of cheatgrass (*Bromus tectorum*) throughout its eventual range in the United States. From Mack (1981).

indigenous weeds as being both managed for and managed against, depending upon the circumstances.

Cheatgrass has a profound effect on sagebrush-grass rangelands by replacing perennial native grasses. It does so by extending its root growth through the entire soil solum during winter months, then extracting all soil water in the spring, causing perennial grass seedlings to die (Harris 1967). Once it becomes established, cheatgrass creates a positive feedback in association with wildfire by depleting the vigor and abundance of perennial grasses. Cheatgrass allows hot fires to occur earlier in the spring when perennial grasses are physiologically susceptible to burning (Wright and Klemmedson 1965). The resulting extended fire season, in turn, creates conditions for cheatgrass to maintain dominance. Overgrazing exacerbates these dynamics (Pechanec et al. 1954).

In pinyon-juniper woodlands, cheatgrass and fire can jointly create a threshold that prevents re-establishment of the original woodland. Tausch (1999b) has submitted that a number of woodland and sagebrush rangeland ecosystems in the Great Basin have crossed thresholds created by non-indigenous species, but the full effect of these species are as yet unknown.

## Other Non-Indigenous Weeds

The species described above may be the most prevalent weeds on U.S. rangelands, but a number of other invasive plants pose present or potential problems to agency managers and private landowners alike. A short and non-exhaustive listing of other weeds is presented in table 3.28. The Council for Agricultural Science and Technology (CAST) has published an issue paper on invasive plant species that contains a list of 60 rangeland/wildland economically and ecologically important invasive weed species in the United States (CAST 2000).

## Non-Indigenous Weeds on National Forest System Lands

Estimated weed abundance is shown, by Forest Service Region, in table 3.29. The supporting data for the totals shown were derived from expert-opinion estimates at the individual National Forest level.

As can be seen from the median estimates, distributions are highly skewed among Forests within Regions and among Forest Service Regions within the United States. For example, in the NO Assessment Region about

**Table 3.29**—Total area infested by non-indigenous weeds on National Forest System lands, by Region, and area infested by median National Forest in Region, 1998.

| Forest Service Region | Area (ac. $10^3$) |
|---|---|
| Northern, R-1 | 1,181.1 |
| Median Forest (n = 13) | 40.0 |
| Rocky Mountain, R-2 | 376.2 |
| Median Forest (n = 10) | 23.6 |
| Southwestern, R-3 | 193.8 |
| Median Forest (n = 11) | 2.0 |
| Intermountain, R-4 | 805.0 |
| Median Forest (n = 14) | 26.2 |
| Pacific Southwest, R-5 | 60.6 |
| Median Forest (n = 12)[1] | 2.6 |
| Pacific Northwest, R-6 | 454.8 |
| Median Forest (n = 20) | 10.0 |
| Southern, R-8 | 200.0 |
| Median Forest | No data |
| Eastern, R-9 | 295.6 |
| Median Forest (n = 15) | 13.5 |
| Total, All Regions | 3,567.1 |
| Median Region (n = 8) | 335.9 |

[1] *Two forests and the Lake Tahoe Basin Management Unit did not report weeds data.*

two-thirds of all NFS lands infested with non-indigenous weeds can be found on three National Forests, the Bitterroot, Idaho Panhandle, and Lolo. In the Southwestern Region, a single National Forest, the Coconino, accounted for almost 90 percent of all infested acres reported (unpublished data). The lack of spatial evenness seems to be a characteristic of weeds at different spatial scales, especially at regional and national levels (see discussion above, Rejmánek and Randall 1994, Lonsdale 1999).

## Future Impacts of Non-Indigenous Plants

The future extent of non-indigenous weeds in the United States will depend upon the rate that non-infested rangelands become occupied and the rate of recovery on lands already infested. Given that disturbance is a natural process on rangelands regardless of how they are managed, one can conclude that alien weeds will continue to invade into areas previously unoccupied.

The potential for invading rangelands, either by new species or existing species from surrounding locations, is high. Increasing trade and travel will facilitate new pathways for species exchange across national borders, thereby exposing U.S. rangelands to weeds previously not seen (U.S. Congress, Office of Technology Assessment 1993). Broadened interest in ornamentals is allowing non-indigenous plants to escape into natural areas. For example, the forb Japanese knotweed (*Polygonum cuspidatum*) has escaped from urban landscapes in the Pacific Northwest and is rapidly escalating in riparian zones from Oregon to Montana (personal communication with Andrew Kratz, USDA Forest Service, Rocky Mountain Region, Denver, CO). It forms thick stands that are presently unaffected by hand treatments or herbicides.

Even though we should expect future non-indigenous weed invasions onto U.S. rangelands, drawing conclusions about potential patterns of plant invasions is not easy (Lonsdale 1999). Once a species is established, research can only sometimes appraise its potential for expansion into uninvaded areas (Chicoine et al. 1985). Some theoretical reaction-diffusion models of how invasive species spread have been validated as accurate, but others have been shown to have large error terms (Hastings 1996). Stochastic models may furnish better insight into modeling how weeds spread from initial invasion patterns.

Reichard and Hamilton (1997) have advanced the possibility of being able to predict invasive success on the basis of plant attributes and climatic range. Under their proposed scenario, protocols could be developed to screen intentional introductions of alien species, leaving mostly the impacts from unintentional invasions to cause problems in natural ecosystems. However, Mack (1996) argued that predicting plant invasions is not easy because "climate-matching" fails to account for different biotic restrictions among regions, and models based upon initial rates of spread are inaccurate because they lack critical spatial pattern recognition. Mack called for experimental approaches to complement theoretical models for determining invasibility. Thus, our facility for forecasting weed invasions in order to mitigate future impacts is somewhat ambiguous.

Researchers are divided about the outlook for controlling invasions of non-native plants. When speculating about coming years, they tend to fall into the two camps: optimism and pessimism (U.S. Congress, Office of Technology Assessment 1993). In general, those working in biological control research hold the encouraging perspective that biocontrol agents will hold down future impacts by up to one-third of introduced weed species (McFadyen 1998). At the other end of the spectrum lie environmental organizations and many state and federal agencies that see invasive species increasing in a geometric progression (Williams 1997, Federal Interagency Committee for Management of Noxious and Exotic Weeds 1998). Some scientists are expecting a continuing wave of introductions from rangelands in other countries climatically similar to the United States such as China, South Africa, and Argentina (unpublished testimony of Peter M. Rice, University of Montana, to Senate Agriculture Committee, Hearing on Noxious Weeds, 8 May 1999, Nampa, ID).

The most likely outcome will lie between these two extremes. Several investigators working in biological control acknowledge the effectiveness of introduced organisms in successfully controlling some weeds like tansy ragwort (*Senecio jacobaea*)(McEvoy et al. 1991), but question whether simply adding natural enemies will check or reverse an invasion regardless of the local or environmental conditions, particularly in an uncertain future (McEvoy and Coombs 1999).

Little work has been done on balancing the risks of introducing new releases versus the benefits accrued from such actions (Simberloff and Stiling 1996, Louda et al. 1997). Rejmánek and Randall (1994) have demonstrated that the rate of non-indigenous species establishment is slowing somewhat in California, a state with one of the highest densities of alien species.

There is inadequate understanding about the degree to which episodic events such as droughts and extreme fire years will accelerate the spread of non-indigenous weeds. For example, large areas of Nevada and adjoining Intermountain states burned during the summer of 1999, and some rangeland scientists are expecting cheatgrass to spread extensively in this region. Klemmedson and Smith (1964) and Young and Longland (1996) discussed how fire can intensify the rate that cheatgrass increases in abundance and distribution. If infrequent episodic events do cause unforeseen levels of expansion by alien plants, present rates of increase may be maintained well into the 21st Century.

Collectively, riparian and aquatic habitats are perhaps the most crucial rangeland ecosystems when it comes to invasibility. Purple loosestrife, Russian olive (*Elaeagnus angustifolia*), saltcedar, and Japanese knotweed have been rapidly spreading in these ecosystems (Cartron et al. 2000). A free-floating aquatic fern, giant salvinia (*Salvinia molesta*) has recently invaded ponds, oxbows, and slow-moving streams from the Atlantic Coastal Plain to central California. This weed can quickly form thick mats that threaten aquatic plant and animal life (Oliver 1993). Stohlgren et al.'s (1999) conclusion that plant communities with high canopy cover, soil fertility and species diversity are most likely to be hot spots for expanding exotics points to riparian zones as a potential target. Such a conclusion should be tempered with the understanding that not all riparian areas are exceptionally diverse when compared to other kinds of ecosystems (Baker 1990).

# Summary

The status of our Nation's rangelands can be ascertained on the basis of various standards. In general terms, rangeland health is connected to the broader concepts of sustainability and sustainable management. One standard, the Montreal Process (USDA Forest Service 1997), is appropriate for evaluating rangeland sustainability at a national scale through seven criteria: biological diversity, productive capacity, ecosystem health, soil and water conservation, contribution to the global carbon cycle, multiple socio-economic benefits, and a legal-institutional-economic framework (Mitchell et al. 1999a). The first four criteria are summarized in turn below. Criterion 7 is the subject of Chapter 5. Insufficient information is available for an effective discussion of the other two criteria at this time.

## Biological Diversity

Extent of area by rangeland type and successional stage is an important indicator of biological diversity. More than half of all the ecosystem types determined to be critically endangered (i.e., >98 percent of area has been lost or ecologically degraded) are grasslands or shrublands (Noss et al. 1995). This sum is weighted heavily, however, by the near-total disappearance of tallgrass prairie and extensive conversions of the mixed grass plains to agricultural use prior to the 1930's (Samson and Knopf 1994). Much of the remaining land base is stable. Additionally, some studies showing such total losses of native cover tend to overlook smaller tracts because of the large pixel size (1 km) used in data analysis (Sieg et al. 1999). Thus, rangeland type should be judged by both actual extent and long-term trend. There is no indication that endangered rangeland ecosystem types are now being lost except for desert grasslands (Schlesinger et al. 1990, Grover and Musick 1990, Loftin et al. 2000) and aspen (Bartos and Campbell 1998).

The Nature Conservancy and other non-governmental organizations have been working to protect endangered ecosystems and enhance biodiversity by preserving critical ecosystems (Mitchell et al. 1999b). If pockets of threatened and endangered species are broadly distributed across the Great Plains, as may be the case (Sieg et al. 1999), it may be possible to reclaim species biodiversity by a combination of ecosystem protection and good management.

Rangeland area by successional state has been addressed in this chapter. Recall that range health is closely correlated with species composition, which is tied to successional stage. Trends in range condition range from static to improving in the PC and RM Assessment Regions across all land ownerships. Overall the trend seems to be one of slow improvement since the last Assessment (Joyce 1989) except for a few arid and semiarid ecosystems that have already crossed thresholds where recovery to previously existing PNC's is not feasible in the short term. Such ecosystems are mostly static, or in some areas such as those with extensive infestations of non-indigenous weeds, still declining. A dichotomy exists in the SO Assessment Region, where NFS grazing lands are in good condition and fairly static but non-federal land condition seems to be in a downward trend.

## Productive Capacity

National Montreal Process indicators for productive capacity address the area of rangeland and total biomass available for grazing, and the annual removal of forage compared to that determined to be sustainable. Monitoring and documenting these indicators are difficult, and have not been adequate (McArthur et al. 2000). However, given the projection that livestock utilization of grazing land will decrease in the PC, RM, and NO Assessment Regions and not change significantly in the Southern Assessment Region (Van Tassell et al. 1999), we can expect that the overall U.S. productive capacity will not be degraded.

## Ecosystem Health

Three indicators gauge the maintenance of ecosystem health under the Montreal Process: Area and percent of rangeland affected by processes or agents beyond the range of historic variation; area and percent of rangeland subject to specific levels of air pollution or ultraviolet B that may cause negative ecosystem impacts; and area and percent of rangeland with diminished biological components indicative of changes in fundamental ecological processes (USDA Forest Service 1997).

Invasions of exotic species, fire, drought, and grazing are examples of agents and processes that have apparently occurred beyond their range of historic variation on U.S. rangelands during the past 150 years. Fire is a natural and important component of many U.S. rangelands, but fire prevention and suppression programs over the past 70 years have resulted in a major shift in fire frequencies (figure 3.10). Prolonged drought reduces plant cover, thereby increasing erosion potential over large areas following the drought (Thurow and Taylor 1999). Non-indigenous weeds and grazing also have been considered in this chapter.

The vast expanses and remoteness of rangelands, both in the United States and globally, create difficulties in assessing these indicators of health and vitality. No national monitoring framework is in place to collect data on long-term and episodic processes and agents over

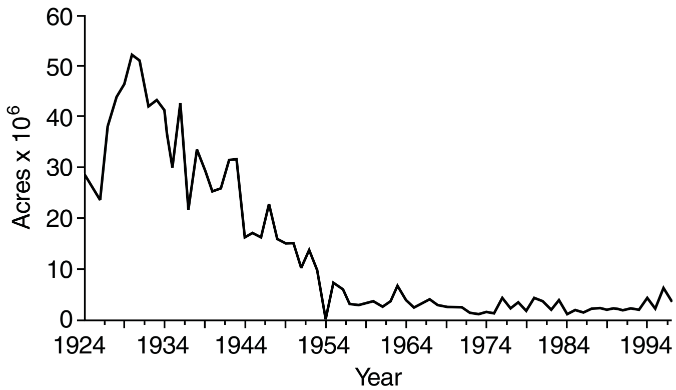



**Fig. 3.10—**Land area burned in the United States, 1924 to 1997. Data from USDA Forest Service as presented by The Heinz Center (1999). The acreage covers lands managed by agencies in U.S. Department of Interior and U.S. Department of Agriculture, as well as private lands.

time. The best data available for the ecosystem health criterion may be for its second indicator because of national networks to monitor air quality (Joyce et al. 2000).

## Soil and Water Conservation

A number of indicators have been developed as part of the Montreal Process for evaluating how well a nation maintains its soil and water resources. Among them are the area and percent of rangeland with significant soil erosion and percent of stream length in which stream flow and timing have significantly deviated from the historic range of variation (USDA Forest Service 1997). National data sets do exist for soils, water quality, and streamflow, but they have such varying degrees of coverage, compatibility, and recency that comprehensive analyses of them are problematic (Neary et al. 2000). The Proper Functioning Condition approach for rating the health and functioning of riparian zones, described above, could well serve as an adequate method for reporting the percent of stream reaches with abnormal stream flow and timing (Neary et al. 2000).

No hard rules exist for summarizing these or other criteria to determine rangeland health. Individual conclusions will vary from person to person and organization to organization. Thus, any collective overview can only be reached through values and objectives of society as expressed in goals and objectives, primarily through society's refinement process of laws and regulations (Shields and Mitchell In press).

# Chapter 4: Maintenance of Productive Capacity

## Introduction

The Assessment required in the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) is to include "an analysis of present and anticipated uses, demand for, and supply of renewable resources." Forage supplies, in particular grazed forages, comprise the predominant renewable resource on rangeland, although other resources such as wildlife habitat, water, timber, minerals, and recreational opportunities are also jointly provided. Collectively, forage and other resources characterize a nation's rangeland productive capacity.

Numerous factors are correlated with and affect the value of grazed forages. The future supply of forage is a function of changes in forage productivity and the extent of land available to produce forage (Joyce 1989). Quantifying either of these factors is not a trivial task, however. Across broad scales, primary production on rangelands is limited by fairly constant abiotic factors such as mean annual precipitation, potential evapotranspiration, temperature, and soil texture (Webb et al. 1983, Sala et al. 1988, Epstein et al. 1997). Therefore, any increases in production will rely upon advances in technology, rangeland restoration based upon existing technology that largely rely upon increasingly uneconomical energy inputs (Workman and Tanaka 1991), and/or substantial and widespread changes in rangeland health (Committee on Rangeland Classification 1994).

Technological developments can be analyzed within the framework of Criterion 6 (Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies) and Criterion 7 (Legal, institutional and economic framework for forest conservation and sustainable management) of the Montreal Process (Coulombe 1995). For example, as applied to rangelands, Indicator 38 under Criterion 6 would assess the value of investment in rangeland health and management, livestock processing, and recreation and tourism. Indicator 40 refers to the extension and use of new and improved technology. The extent to which the U.S. institutional framework has the capacity to develop and maintain an efficient physical infrastructure to facilitate the supply of rangeland products and services is accounted for in Indicator 56 under Criterion 7 (USDA Forest Service 1997).

Joyce (1989) estimated that technology could result in a doubling of forage production in the Southwest and Pacific Northwest by the year 2040. As a result, U.S. rangelands as a whole were expected to have the capability for substantially increasing forage productive capacity. Joyce's deduction was made in part on the basis of a 2 percent annual growth in research, development, and extension expenditures, and expected gains in technologies originated for croplands that could have applications for boosting pasture and rangeland forage production.

The average annual growth of real output per capita has increased in nearly every country since the end of World War II. The growth has been fueled by expanding access to education, increased savings and investments, advances in technology, and better integration of countries into the world economy (Bayoumi 1995). At the same time, however, commitments to science and technology are becoming less prominent among some U.S. mission agencies, a circumstance that could foretell a slowing of our international involvement in this arena (Watkins 1997). Given the myriad and varied changes around the world during the past decade, it is appropriate to revisit how changing technology may or may not affect future rangeland forage production.

Improving rangeland health relies more heavily on using ecological tools rather than advances in technology (Heady and Child 1994). From a national perspective, measures of rangeland health are found within two Montreal Process criteria, Criterion 2, productive capacity, and Criterion 3, maintenance of ecosystem health (McArthur et al. 2000, Joyce et al. 2000). Factors to be evaluated within these domains include the total biomass from rangeland available for grazing, removal of rangeland biomass and other products compared to the level determined to be sustainable, the influences of processes or agents beyond the range of historic variation, effects of air pollutants on rangeland function, and the area of rangeland with diminished biological components.

## Advances in Technology

### Research and Development Budgets

National budgets for research and development (R&D) face uncertain futures in many developed countries at the close of the 20th Century. In the U.S., federal research funds outside of those allocated for health issues face nearly continuous scrutiny because of political desires to decrease spending while simultaneously funding specified domestic programs such as highways (Lawle 1998).

The European Union's research itinerary for the years 1998–2002 may be reduced $1.9 billion from what was proposed by their Commission (Williams 1998). Recent financial crises in east Asian countries are combining with their culture of science to at least temporarily limit R&D, even in those countries that have a recent history of emphasizing research in their development plans (Mervis and Normile 1998).

National funding for R&D is always expected to rise and fall with recessions. Longer term trends will likely depend upon factors such as the peace dividend, aggregate savings, possible debt crises, and global economic integration. No obvious future global tendencies for these factors have been documented. Even under conditions of low inflation and a large government budget surplus, federal research spending faces an uncertain fate as long as social programs such as Social Security and Medicare appear to be in long-term jeopardy (Mervis and Malakoff 1999).

Although worldwide military spending decreased by 3 percent of gross domestic product (GDP) between 1985 and 1995, the resultant "peace dividend" of about $345 billion has been largely returned to the private sector through lower deficits or lower taxes instead of being used to increase other spending (Clements et al. 1997). A number of low-intensity national conflicts during the 1990's has increased the world demand for arms, thus helping blunt any tendency for decreased arms spending (United Nations 1997). On the other hand, at least one simulation analysis indicates that the GDP is an unreliable estimator of economic benefits accruing from military spending cuts, and that lower taxes and government spending reduce interest rates, which cause private sector spending on investment and consumption (including R&D) to be notably increased (Arora and Bayoumi 1994).

Nations' gross national savings are generally seen as being important to help sustainable growth. Over the past 25 years, savings rates of both industrial and developing countries, including the United States, have dropped abruptly (Aghevli and Boughton 1990). Whether this downswing will greatly influence the long-term growth rates or domestic investments depends upon government policy and other factors, however (Bayoumi 1990).

The inability of developing countries to service their debts can deny access to private international capital, possibly leading to the incapacity to carry out R&D programs over an extended period (Fischer and Husain 1990). A number of economically developing countries with important rangeland bases are presently classified as severely indebted: Argentina, Ethiopia, Kenya, Mexico, and Russia (Ahmed and Summers 1992).

Economic integration, the ratio of international trade to GDP, has been seen as a reliable indicator of a country's participation in the world economy and, thus, its exposure to new technology (Brahmbhatt and Dadush 1996). Integration of most countries has risen rapidly in recent years, in great part because of liberalization actions precipitated by the General Agreement on Tariffs and Trade (GATT) and the international structure of private corporations (Qureshi 1996). Whether the financial integration of developing countries as a whole will continue is yet to be seen. While the developed world as a whole has become more integrated, the extent and rate of integration varies widely among developing countries (Brahmbhatt and Dadush 1996).

Progress in crop production technology faces a less clear situation than was prevalent one decade ago. Recent World Bank studies indicate that global agricultural production growth rates slowed from 3.0 percent in the 1960's to 2.0 percent during 1980–92, and this percentage is expected to slip to 1.8 percent by 2010 (Ruttan 1991, Alexandratos 1995). The gradual growth of world food production is slackening because of a decline in demand in those countries that can afford food, and insufficient personal incomes in countries whose people would consume more food, if available (Ingco et al. 1996).

## Advances in Agricultural Technology

Early agricultural advances in developing countries were established by transferring technologies and management practices of the developed countries for a few agronomic crops with high production potential—the green revolution. Several undesirable consequences of the green revolution have been identified, particularly the implied objective of maximizing yields regardless of system stability (Daily et al. 1998). Excluding the technological needs of arid regions is another problem. Regardless, the prevailing technological direction is expected to continue over the next 15 years (Alexandratos 1995), although the most likely outcome is for the green revolution to become less and less effective (Mann 1997).

If a real innovation in forage supply happens during the projection period for this Assessment, it most conceivably will involve biotechnology. Discoveries in biotechnology have provided numerous breakthroughs for industrial development of beneficial ways to prevent or treat illness, make better use of energy sources, and produce more nutritious foods (President's Council of Advisors on Science and Technology 1992). In agriculture, the central emphases for biotechnology during the first half of the 21st Century are expected to focus upon food safety, gene sequencing and mapping, metabolic studies leading to new uses for plant materials, and animal growth and development (U.S. National Science and Technology Council, Biotechnology Research Subcommittee 1995).

Biotechnology holds some promise of being able to lessen existing biological limitations on agricultural production by improving tolerances to different physical stresses (Platais and Collinson 1992). Other problems in

American agriculture being resolved with biotechnology include biological control of non-indigenous weeds and insects, and improving the metabolic efficiency of domestic herbivores for meat and milk production (Persley 1990). Some scientists see the most profound consequence of biotechnology in future years to be in the field of altering the chemical composition of plants and animals to improve their nutritional value for food (Bills and Kung 1992). Disputes over environmental risks identified with genetically-modified food plants may measurably slow the application of genetic engineering, and perhaps other forms of biotechnology (Ferber 2000).

Biotechnology is also increasingly concentrating upon environmental health—studies of the origins, pathways, and outcomes of chemical contaminates that may elevate risks to human health—rather than the broader subject of ecosystem sustainability (Rapport 1998). Gene therapy and other new biologies are also part of a larger biotechnological research program in environmental health (Rudolph and McIntire 1996).

Unfortunately, there is no way to assess how discoveries in biotechnology will improve rangeland forage production. To benefit rangeland forage production, research and development will have to eventually shift toward improving technologies for more marginal areas using species other than those with high yield potentials (Hazell and Ramasamy 1991). Moreover, until world research priorities shift toward the inclusion of arid and semi-arid regions, increases in global forage production because of new breakthroughs in technology are not expected to be significant. An important exception could be in the above-mentioned area of pest control. Even the expanding discipline of biological control poses environmental risks if not employed in a deliberate and careful manner, a condition that may limit widespread application of this aspect of biotechnology (Louda et al. 1997).

One area that shows promise is the integration of new findings in genetics to promote maintenance of the genetic variation in forage plant materials necessary for adaptation to changing environments. If genetic concepts can be broadly integrated into planning for rangeland seedings, discussed in the section below, increases in productivity may result in small national benefits not presently anticipated (Jones and Johnson 1998).

## Application of Existing Technology

Agricultural technology is being called upon to achieve goals associated with sustainable land management, including decreased soil erosion and improved water quality and quantity, both ground- and surface-based (Magleby et al. 1995, Committee on Long-Range Soil and Water Conservation 1993). Nonetheless, further advances in existing technology will have to be profitable if U.S. agriculture is continue in its course of economic development. Some researchers foresee limits to developing so-called green technologies because of a lack of markets and intrinsic social barriers to adopting new practices (Hrubovcak et al. 1999). These same impediments should apply to the management of private rangelands for livestock production.

Forage production can be increased by implementing existing rangeland restoration practices that modify species composition and/or vegetation structure to improve forage production from desirable species. Promoting species that further management objectives has led the Forest Service, Bureau of Land Management (BLM) and Natural Resources Conservation Service (NRCS) to differentiate between potential natural community (PNC) and desired plant community (DPC) (USDA Natural Resources Conservation Service 1997):

PNC: The biotic community that would become established on an ecological site if all successional sequences were completed without human interference under the present environmental conditions.

DPC: One of several plant community types that may occupy an ecological site that meet both the manager's objective and the minimum quality criteria for the soil, water, air, plant, and animal resources.

Desired plant communities may result from modification of vegetation by mechanical means, seeding, chemicals, prescribed fire, biological control, fertilization, or various combinations thereof (Heady and Child 1994). Little information exists at a national scale that depicts trends and effects of these treatments on forage production.

Mechanical brush clearing has been used to increase the forage supply for many years, particularly in areas invaded by woodland tree species (Miller et al. 1995). In pinyon-juniper stands, herbage production tends to follow a negative exponential distribution with increasing overstory canopy, staying fairly low until canopy cover approaches zero (Pieper 1983). Seeding and herbicides can be used independently or in conjunction with mechanical treatments. The former is expedient where terrain, soils, and available precipitation can provide a reasonable chance of stand establishment, and native forage species are lacking (Plummer et al. 1955). Herbicides have historically been used for brush control (Young et al. 1981), but they are now being increasingly applied as a component of integrated pest management in controlling invasive plants (Lym et al. 1997).

The annual rate of brush control and seeding on lands managed by the BLM has not changed significantly since 1980, even though the apparent trends seem to be down for seeding (figure 4.1) and up for brush control (figure 4.2). The median areas seeded and cleared of brush annually on BLM lands during this period have been about

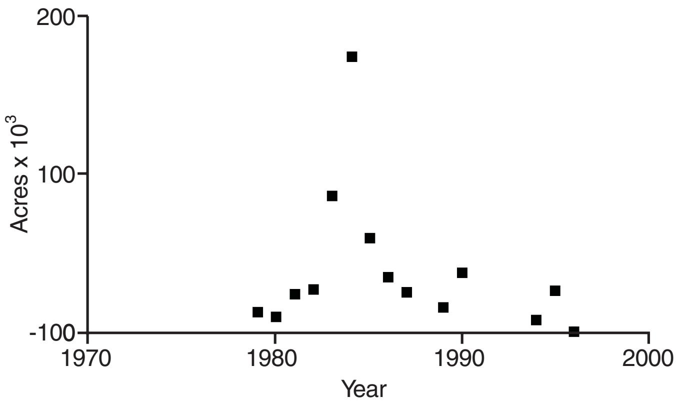



**Fig. 4.1**—Rangeland managed by USDI Bureau of Land Management seeded to forage species as a range improvement practice, 1979–1996 (Public Land Statistics, various years).

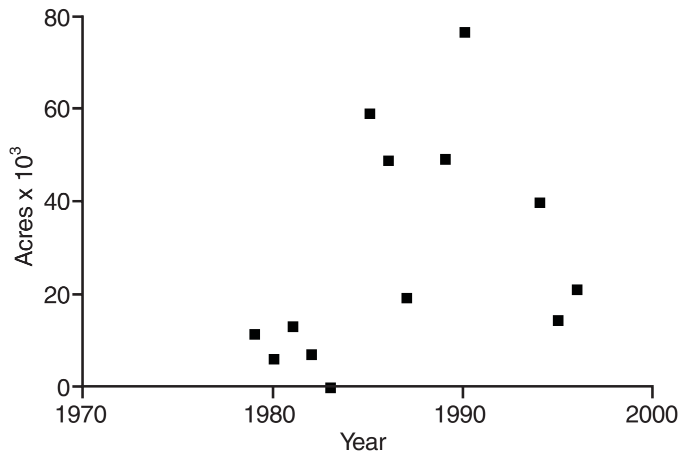



**Fig. 4.2**—Rangeland managed by USDI Bureau of Land Management cleared of brush and trees as range or watershed improvement practices, 1979–1996 (Public Land Statistics, various years).

27,000 acres and 20,000 acres, respectively. Nonstructural range restorations, not counting treatment of noxious weeds, has declined from 35,200 acres during the mid-1990's to 23,800 acres in 1990; this short-term trend reflected decreased funding (USDA Forest Service 1999). These statistics are not significant from a national perspective. Additionally, the strategic plans of both the Forest Service and BLM contain performance goals emphasizing restoration of riparian areas and high-priority watersheds over lower-priority upland sites. Thus, mechanical improvements, seeding, and herbicide applications are not anticipated to significantly increase the Nation's forage supply in themselves over the next 50 years.

For rangelands as a whole, it is not possible to project the impact of dynamics in the distribution and development of woodlands over the next 50 years. Tausch (1999b) has concluded that the next 150 years could actually bring about a considerable reduction in the area dominated by pinyon-juniper because of large fires arising from extensive stands with close canopies. Other areas of the United States will likely see continued increases in undesirable woody species (Archer 1994).

Some technological advances in rangeland management will be directed towards goals that do not directly improve the Nation's forage supply, for example those mitigating impacts on water quality (Binkley and Brown 1993).

## Changes in Rangeland Health

Because the U.S. rangeland health situation is described in Chapter 3, this section is limited to a prognosis for increased forage production available for consumption by wildlife and domestic livestock in response to expected changes in rangeland health or condition.

Research has shown that productivity and diversity are related to the extent that rangeland has been degraded (Reid 1946, Breman and de Wit 1983). Thus, if broad advances in range condition can be attained, the supply of forage will be increased, at least in mesic ecosystems. In arid and semiarid rangelands, however, productivity can inexorably decline once degradation passes certain thresholds (Milton et al. 1994).

Aside from the condition of private rangeland in the South (SO) Assessment Region, the results presented in Chapter 3 do not portray many opportunities for significant increases in available forage from U.S. grazing lands in the near term. Trends are not improving in areas with the best capacity for positive change—the mesic South and Southeast. Major ecosystems dominating the southwestern part of the Rocky Mountains (RM) Assessment Regions are not capable of rapidly recovering to higher ecological states, either, because of the imposition of thresholds and the slow nature of succession in arid and semiarid rangelands (Friedel 1991, Laycock 1991).

Numerous individual "success stories" have been recorded where range forage quality and production have been spectacularly advanced by good management practices (Masters et al. 1996, Bradford 1998). However, one cannot conclude that (1) these management-unit achievements will be manifested in a greater forage supply regionally than is revealed in the trends shown in Chapter 3, or (2) any increased forage production will lead to increased livestock stocking levels or cause wildlife populations to expand on a regional scale.

Perceived conflicts between grazing and biodiversity, risks to threatened and endangered species, and water quality have led some environmental organizations to employ lawsuits and other mechanisms to limit livestock numbers on federal land (Kenworthy 1998). Propositions to eliminate livestock grazing from large tracts of semiarid and arid public western rangelands will tend to counter any plans to increase the broad use of added forage by livestock (Donahue 1999). These actions are consistent with a scenario analysis by Van Tassell et al. (1999) that forecasts a higher likelihood for decreased livestock utilization of grazing lands in the RM and Pacific Coast (PC) Assessment Regions than for outcomes where grazing levels are maintained or even increase.

Steps to limit livestock grazing on public lands are being taken even though ample evidence exists that most rangeland landscapes and plant communities can tolerate a certain degree of herbivory (Vavra et al. 1994). For example, Holechek et al. (1999) have concluded that a stocking rate that consumes only 30–35 percent of available forage, with some destocking in drought years, will maximize profits while maintaining range condition in the desert Southwest. The above paradox was recognized by R.K. Heitschmidt at a recent symposium on the Great Plains when he stated that managed grazing is ecologically sustainable, although not always economically viable or socially acceptable (Mitchell et al.1999b).

Nationally, harvests of pronghorn, deer, and elk have been climbing since the mid-1970's, although long-term projections over the next 50 years do not show a continued increase (Flather et al. 1999). While changes in harvest rates reflect total population sizes, there is no basis to explain why such changes have or are expected to take place. Forage supply cannot be singled out as a primary causal factor, although it can be important (Caughley 1970). Thus, the allocation of any increased forage resulting from improved range condition to wildlife is uncertain, but expected (Van Tassell et al. 1999)

### Riparian Areas

Perhaps the greatest potential for increased forage production in response to improved rangeland health within the more xeric RM and PC Assessment Regions will come from riparian areas (figure 4.3). Three considerations drive this assumption: First, riparian zones can account for five or more times the production of available forage than uplands on a per unit area basis (Roath and Krueger 1982). Second, degraded riparian ecosystems can recover to a productive state in relatively few years compared to uplands, once proper management practices are implemented (Alford 1993). Finally, although a comprehensive appraisal of our Nation's riparian areas has not yet been undertaken, even on public lands (USDI Bureau of Land Management 1991), there is evidence that some western riparian areas are not in good condition because of improper grazing by cattle. Extensive beaver trapping and more recent ill-conceived physical modifications of stream channels for flood control, irrigation, and wetland conversion have exacerbated the situation (Chaney et al. 1990, Elmore and Kauffman 1994).

Regardless of its collective potential for increased primary production, riparian areas cannot be counted on to provide greater forage supplies over the next 50 years. On public lands, riparian areas often constitute the most critical locations for multiple-use planning because of their limited spatial extent; great importance for grazing, wildlife, and biodiversity; high concentration of threatened and endangered species; recreational opportunities; and rapidly increasing public interest (Platts 1979, Kauffman and Krueger 1984, Johnson et al. 1977, Brown et al. 1991, Fort 1993). Whether or not any increased forage resulting from widespread changes in riparian health will become available for consumption by grazing animals will depend in large part upon shifts in public values and objectives (Mitchell et al. 1995).

A 1988 General Accounting Office report concluded that recovery of western riparian areas will be constrained over the foreseeable future by staff reductions in the Forest Service and BLM as well as agency institutional barriers to making needed changes in the field (U.S. General Accounting Office 1988). The problem of staffing remains (see chapter 5), but, on the other hand, the Forest Service, BLM, NRCS, Fish and Wildlife Service, and other agencies have promoted riparian area restoration as a key component in the Clean Water Action Plan announced by the President in February 1998. Since the focus of the Clean Water Action Plan is on restoration and the economic benefits of clean water conveyed therein relate primarily to recreation, tourism, and the commercial fish and shellfish industry, one cannot expect to gain a significantly increased forage supply from riparian areas over the next 50 years.

## U.S. Livestock Production

When assessing the productive capacity of forests at a national scale, the total growing stock of timber is an essential indicator. On rangelands, vegetation in the form of forage may be a principal indicator of productive capacity, but livestock numbers can also act as a measure of a productive capacity from a commodity point of view.

**Fig. 4.3—**Sandhills-mixed vegetation in eastern Colorado in (a) 1907 and (b) 1949. This rangeland had been heavily grazed for years at the time of the first photograph, but was being properly grazed before the time of the second photograph. From McGinnies et al. 1991.

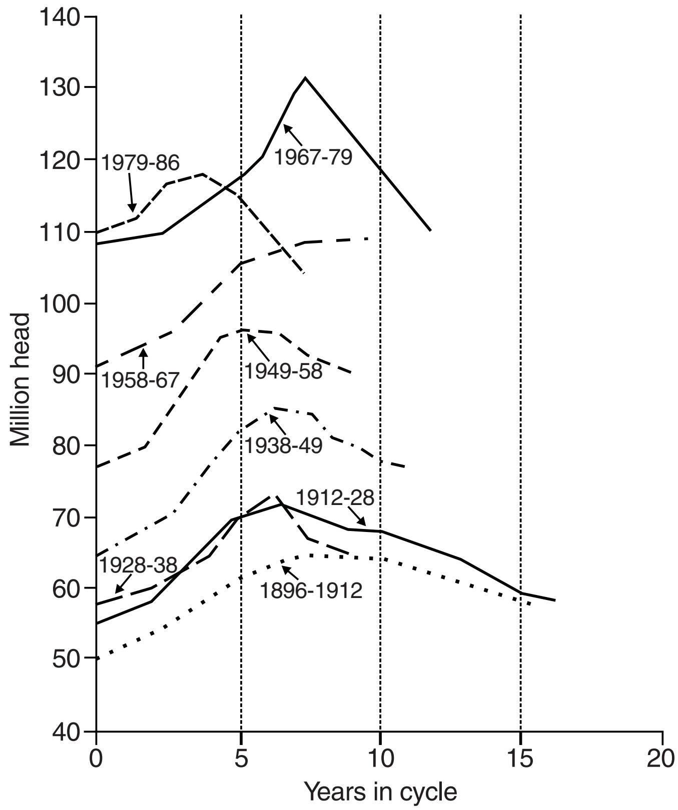



**Fig. 4.4**—United States cattle inventory cycles, 1896 through 1996. From Hughes (1997).

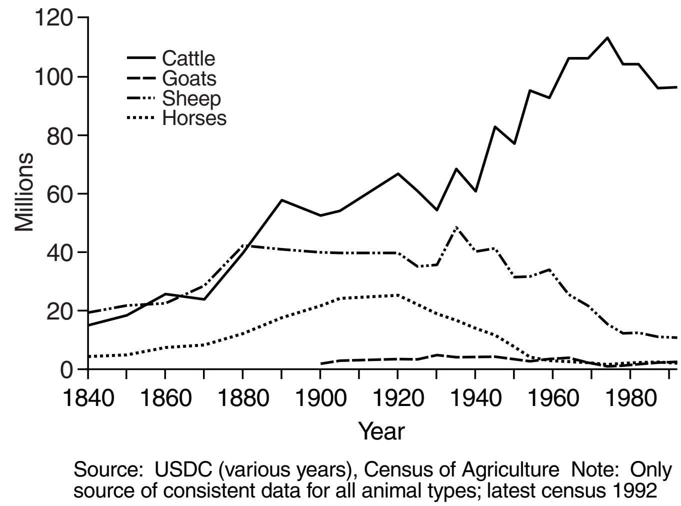



**Fig. 4.5**—Number of livestock on farms in the United States, 1840–1990. (U.S. Department of Commerce, USDA Census of Agriculture — various years).

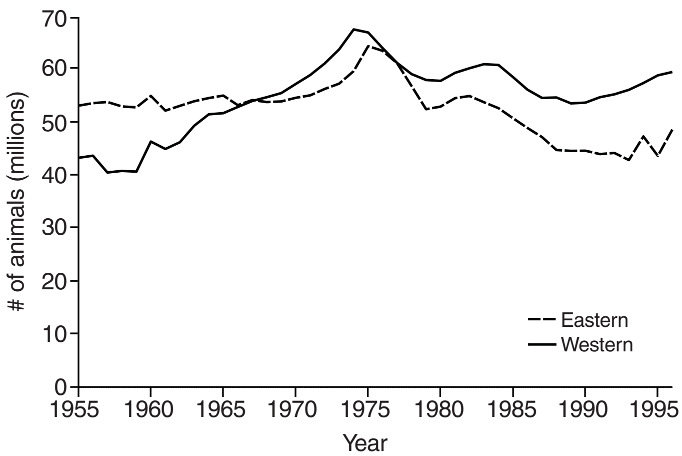
## Cattle and Sheep Numbers

Joyce (1989) described the U.S. historical trends in cattle, sheep, horses, and goats from the mid-1800's until 1986. Cattle and sheep numbers were roughly equivalent from the time records were first made until the 1880's, the decade marking the end of much of the western open range (Mitchell and Hart 1987). From that era, cattle continued to increase until the 1970's; however, sheep remained fairly constant until after World War II, when they began a slow decline (Joyce 1989). Reasons for this decrease included difficulties in obtaining adequate labor, increased costs from predation and for labor, and the need for sheep producers to attain a higher net return in order to maintain production (Parker and Pope 1983, Shapouri 1991). The reduction in lamb packing plants may have exacerbated the difficulties facing woolgrowers by reducing competition for available lambs (Stillman et al. 1990).

The U.S. cattle inventory has undergone cycles since the 1880's. A characteristic cattle cycle lasts roughly 10 years. It can be divided into an expansion stage, where cattle numbers increase following high prices, a turnabout stage that comes in response to lowering prices, and a reduction stage where cattle numbers decline (figure 4.4). The latest national cycle peaked in 1996 at 103.5 million head of all cattle and calves and the reduction stage shows no sign of ending before 2000 (USDA National Agricultural Statistics Service 1999). Like the 1980's cattle cycle, the apex of the present cycle did not increase the national herd size, checking any anticipation of the return to long-term herd buildups that had occurred throughout the Nation's history prior to 1975. The USDA Economic Research Service projects a cyclical low of 97 million head in 2001, followed by only a modest increase to 102 million head by 2007, indicating a continuation of fairly constant cattle numbers from cycle to cycle (Interagency Agricultural Projections Committee 1998).

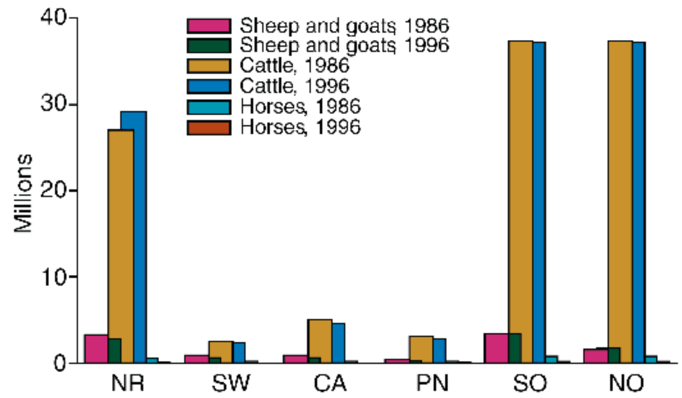
During the 10 years since the last range assessment (Joyce 1989), the 10-year national numbers of cattle, goats, and horses have remained fairly constant (figure 4.5). Horses are now primarily used for various forms of recreation, so their numbers seem to be immune to agricultural economic forces and have not declined at all during the latter 20th Century. The shift of livestock production from the East to the West (all western Assessment Regions plus OK and TX) identified by Joyce (1989) has also apparently steadied at a difference of approximately 10 million more head in the West (figure 4.6). When OK and TX are included in the SO Assessment Region, the two eastern regions have more cattle; again, there do not appear to be significant shifts in cattle numbers between 1986 and 1996 (figure 4.7).

As mentioned earlier, the situation with sheep has been different from that of cattle. Between 1986 and 1993, total U.S. sheep and lamb numbers remained somewhat constant between 10.1 million and 11.4 million animals. By 1996, however, the national herd size had dropped to 8.5 million head. Preliminary data show this total to have




Note: East: NO and SO regions except OK and TX; West: all other regions and OK and TX. Data for 1996 is preliminary. Source: USDA Agricultural Statistics: 1956-1996

**Fig. 4.6**—Number of cattle in the eastern and western United States, 1955–1995. Note: The eastern United States includes the North and South Assessment Regions except for OK and TX, which are included with the western Assessment Regions.




Source: 1986: RPA assessment 1989, 1986 cattle and sheep: USDA Agriculture Statistics 1996;goats and horses:USDCD Census of Agriculture 1998

**Fig. 4.7**—Number of domestic grazing animals in the United States, 1986 and 1996, by Assessment Region.

dropped even further, to 7.6 million head, in 1998. Thus, during the 10-year period between 1988 and 1998, the U.S. sheep industry may have declined by almost one-third (USDA National Agricultural Statistics Service 1991, 1999).

Between 1986 and 1996, the largest percentage decrease in breeding sheep was in the PC Assessment Region, 37 percent. All other Assessment Regions showed a decline of about one-fourth for the same period. Overall, the number of breeding sheep declined from 8.5 million in 1986 to 6.2 million in 1996, a 27 percent drop.

### Distribution of Cattle Operations and Cattle by Herd Size

One of the factors affecting dynamics of the U.S. cattle herd is the distribution of the size of livestock operations. Economies of size stipulate that long-term net revenues on a per-head basis increase with herd size. A 100-cow herd does not provide sufficient cash flow or profit to support a family operation (Godfrey and Pope 1990). According to Harlan Hughes, Extension Livestock Economist, North Dakota University, Fargo (personal communication), family cattle ranches receive an average of approximately $100 per cow.

Lack of management power has the potential to undermine the long-term economic competitiveness of mid-sized farms and ranches. Management power comes from using ranch operational data on land, livestock, labor, and capital to make management decisions. However, recent treaties and losses of commodity support programs are placing more importance on the entrepreneurial nature of agriculture. This, along with the exponentially increasing availability of information on the Internet, is making agriculture more competitive. There is some indication that mid-sized farmers and ranchers are, as a group, too busy to assemble and analyze operational data or to access other sources of information in order to compete with larger operations (Hughes 1999).

Little is presently known about how the distribution of livestock operations and herd size are related to the productive capacity of U.S. rangelands, either public or private. The subject entails an interesting area of needed research.

The vast majority of U.S. cattle operations are too small to sustain themselves economically without other sources of income such as farming or outside jobs. In 1993, only 19 percent of all cattle owners had herds larger than 100 cows. Only 2 percent of all cattle are raised by ranchers with commercial herd sizes of 500 cows or more (table 4.1).

Within Assessment Regions, the distribution of different-sized cattle operations varied greatly in 1993. Nearly 40 percent of operations in the RM Assessment Region had more than 100 cows, compared to less than 20 percent in the each of the other Assessment Regions (table 4.1).

## Grazing Use on Federal Lands

Livestock grazing on BLM and National Forest System (NFS) lands has been stable over the past 30–40 years. On NFS lands, the number of animal unit months (AUM—the biomass of forage consumed by a 1000-lb. cow with a

**Table 4.1**—Distribution of U.S. farms and ranches with cattle, by herd size and Assessment Region, 1993. From USDA National Agricultural Statistics Service 1994.

| Region/State | 1–49 | 50–99 | 100–499 | 500–999 | 1000+ |
|---|---|---|---|---|---|
| **Pacific Assessment Region** | | | | | |
| CA | 17,300 | 1,900 | 3,500 | 1,200 | 1,100 |
| OR | 18,400 | 1,800 | 2,200 | 400 | 200 |
| WA | 17,100 | 1,300 | 2,200 | 250 | 150 |
| Total | 52,800 | 5,000 | 7,900 | 1,850 | 1,450 |
| Percent | 77 | 7 | 11 | 3 | 2 |
| **Rocky Mountain Assessment Region** | | | | | |
| AZ | 2,700 | 500 | 1,000 | 180 | 190 |
| CO | 5,700 | 2,100 | 4,100 | 700 | 400 |
| ID | 7,800 | 1,800 | 2,800 | 380 | 220 |
| KS | 17,800 | 8,400 | 10,300 | 920 | 500 |
| MT | 4,500 | 2,200 | 5,200 | 900 | 300 |
| ND | 4,500 | 3,900 | 6,100 | 430 | 70 |
| NE | 10,500 | 6,400 | 10,000 | 1,200 | 900 |
| NM | 4,900 | 1,200 | 2,100 | 450 | 350 |
| NV | unk | unk | unk | unk | unk |
| SD | 6,300 | 4,200 | 9,700 | 1,300 | 500 |
| UT | 4,400 | 1,100 | 1,900 | 260 | 140 |
| WY | 2,600 | 700 | 1,800 | 500 | 300 |
| Total | 71,700 | 32,500 | 55,000 | 7,220 | 3,870 |
| Percent | 42 | 19 | 33 | 4 | 2 |
| **Southern Assessment Region** | | | | | |
| AL | 24,000 | 4,800 | 3,900 | 240 | 60 |
| AR | 21,500 | 6,000 | 4,300 | 170 | 30 |
| FL | 14,600 | 2,400 | 2,300 | 400 | 300 |
| GA | 21,000 | 4,200 | 3,600 | 150 | 50 |
| KY | 37,000 | 9,400 | 6,400 | 180 | 40 |
| LA | 14,100 | 2,800 | 2,400 | 160 | 40 |
| MS | 21,000 | 4,200 | 3,500 | 260 | 40 |
| NC | unk | unk | unk | unk | unk |
| OK | 39,000 | 10,900 | 10,700 | 900 | 500 |
| SC | unk | unk | unk | unk | unk |
| **Southern Assessment Region (cont.)** | | | | | |
| TN | 52,000 | 8,400 | 5,400 | 150 | 50 |
| TX | 100,000 | 21,000 | 22,500 | 2,100 | 1,500 |
| VA | 20,500 | 4,800 | 4,400 | 250 | 40 |
| Total | 364,700 | 79,800 | 69,400 | 4,960 | 2,650 |
| Percent | 70 | 15 | 13 | 1 | 1 |
| **Northern Assessment Region** | | | | | |
| CT | unk | unk | unk | unk | unk |
| DE | unk | unk | unk | unk | unk |
| IA | unk | unk | unk | unk | unk |
| IL | 21,000 | 5,400 | 4,400 | 190 | 60 |
| IN | 24,000 | 3,500 | 2,400 | 80 | 20 |
| MA | unk | unk | unk | unk | unk |
| MD | 5,200 | 800 | 780 | 10 | 10 |
| ME | unk | unk | unk | unk | unk |
| MI | 12,800 | 2,900 | 3,000 | 250 | 50 |
| MN | 17,600 | 11,100 | 9,000 | 200 | 100 |
| MO | 47,000 | 15,000 | 12,400 | 510 | 90 |
| NH | unk | unk | unk | unk | unk |
| NJ | unk | unk | unk | unk | unk |
| NY | 11,000 | 4,800 | 5,000 | 150 | 50 |
| OH | 32,600 | 4,700 | 3,500 | 170 | 30 |
| PA | 21,000 | 7,100 | 4,800 | 80 | 20 |
| RI | unk | unk | unk | unk | unk |
| VT | 1,500 | 1,300 | 1,200 | 50 | 10 |
| WI | 21,500 | 14,800 | 14,400 | 270 | 30 |
| WV | unk | unk | unk | unk | unk |
| Total | 215,200 | 70,600 | 60,100 | 1,960 | 470 |
| Percent | 62 | 20 | 17 | 1 | 0 |
| All "unk" states | 34,900 | 3,900 | 3,900 | 450 | 120 |
| Total, all states | 739,300 | 191,800 | 196,300 | 16,440 | 8,560 |

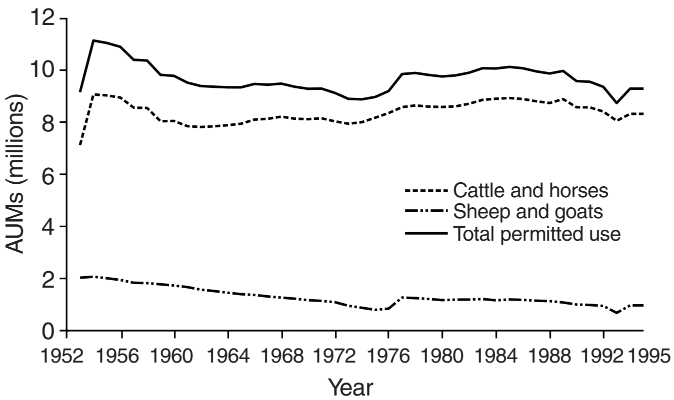
suckling calf in one month, or about 780 lb. dry weight) has varied within 10 percent of 10 million AUM's since 1960 (figure 4.8). Grazing use on NFS lands has also been steady by Assessment Region with the exception of the SO Assessment Region (figure 4.9 through figure 4.14). Cattle grazing on NFS lands in the South has been declining constantly since 1970 (figure 4.13), but its contribution to overall livestock grazing in the region has always been small.

Livestock grazing use of BLM lands has also remained nearly constant at around 10 million AUM's over the past 20 years (figure 4.15). Declines in the Pacific Northwest and California did not involve enough AUM's to affect the national trend (figure 4.16, figure 4.17). Total livestock grazing use on BLM lands in the Intermountain, Rocky Mountain, and Southwestern regions have not notably declined since 1980 (figure 4.18, figure 4.19).

Another way of assessing the extent of livestock grazing on U.S. federal rangelands is to examine trends in non-use. In the last rangeland assessment document, Joyce (1989) defined non-use of cattle and sheep on NFS lands as

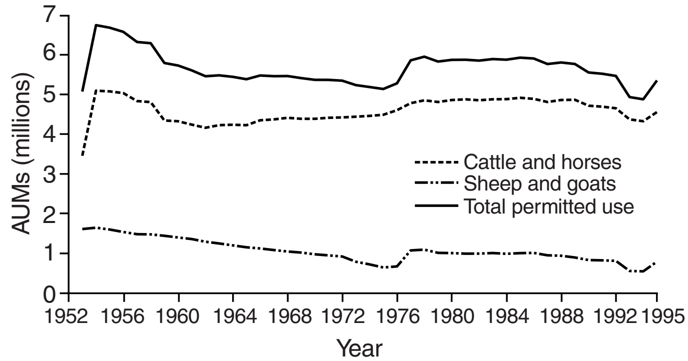
$$1 - (\text{authorized AUM's}/\text{permitted AUM's})$$

where authorized use was the sum of all of paid permits contained in annual authorizations and permitted use



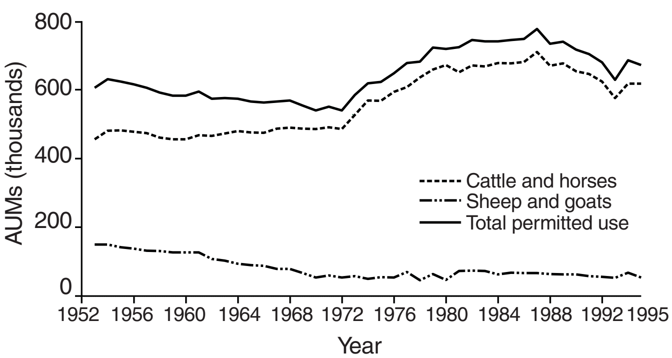

USDA, Forest Service (1978-1995)

**Fig. 4.8**—Livestock grazing use of National Forest System lands, 1953–1995.



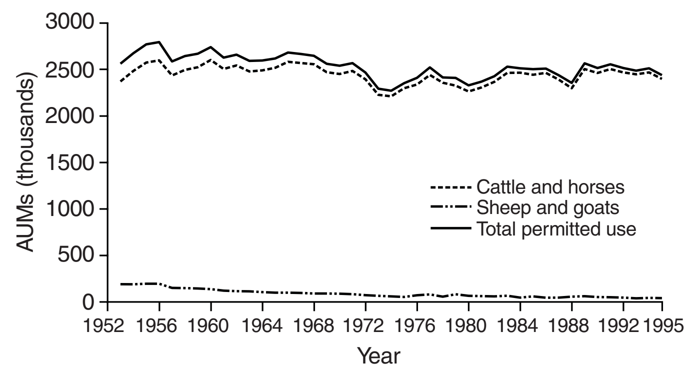

USDA, Forest Service (1978-1995)

**Fig. 4.11**—Livestock grazing use of National Forest System lands, Northern Region, 1953–1995.



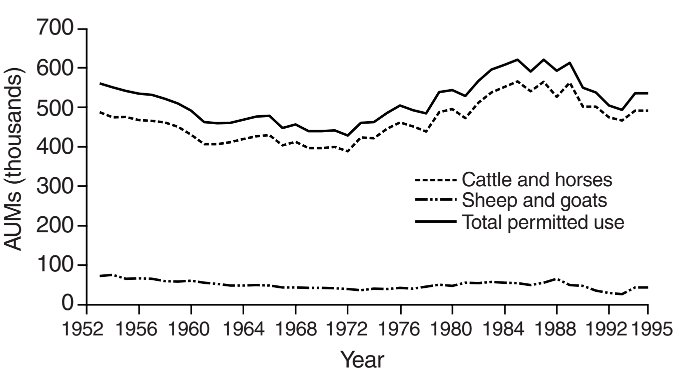

USDA, Forest Service (1978-1995)

**Fig. 4.9**—Livestock grazing use of National Forest System lands, Pacific Northwest Region, 1953–1995.



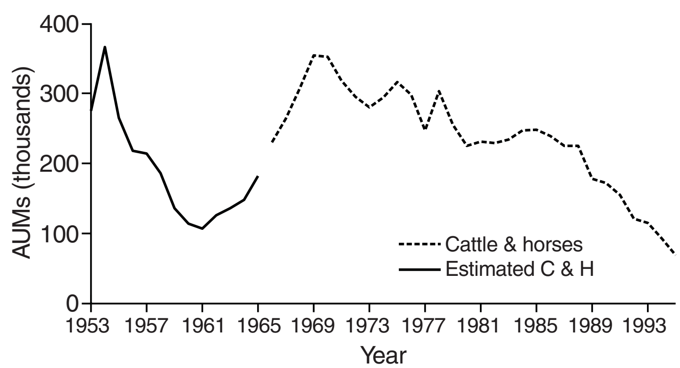

USDA, Forest Service (1978-1995)

**Fig. 4.12**—Livestock grazing use of National Forest System lands, Southwestern Region, 1953–1995.



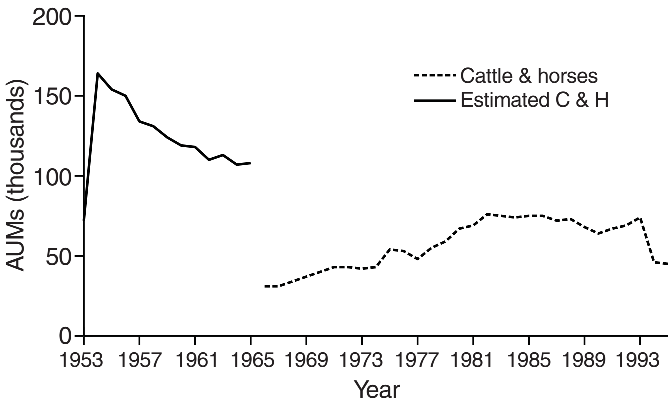

USDA, Forest Service (1978-1995)

**Fig. 4.10**—Livestock grazing use of National Forest System lands, Pacific Southwest Region (California), 1953–1995.



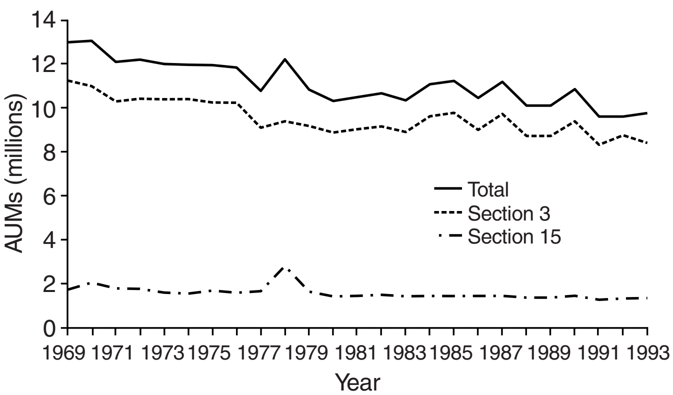

Source: USDA Forest Service (1954-1995)

**Fig. 4.13**—Livestock grazing use of National Forest System lands, South Assessment Region, 1953–1995.



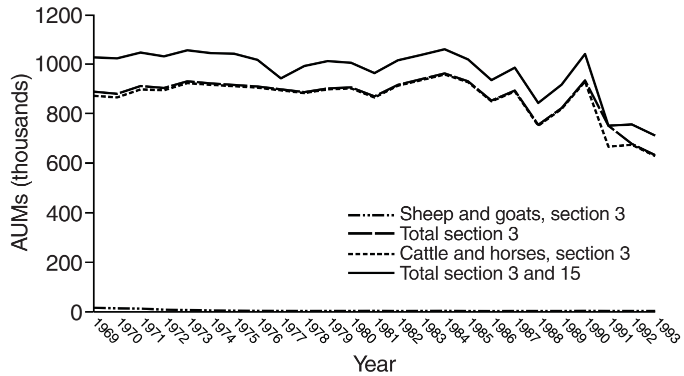

Source: USDA Forest Service, Grazing Statistical Summary: 1954-1995

**Fig. 4.14**—Livestock grazing use of National Forest System lands, North Assessment Region, 1953–1995.



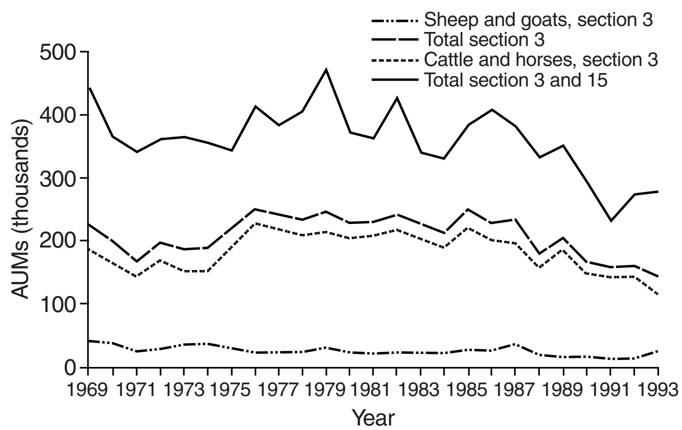

USDI BLM Public Land Statistics: (1970-1994)

**Fig. 4.15**—Livestock grazing use of Bureau of Land Management lands, 1969–1993. All public lands within the boundaries of grazing districts are managed under Section 3 of the Taylor Grazing Act of 1934. These areas contain large blocks of public land. Lands outside the boundaries of grazing districts are managed under Section 15 of the Act. These are mostly small, isolated tracts of land.




USDI BLM Public Land Statistics: (1970-1994)

**Fig. 4.16**—Livestock grazing use of Bureau of Land Management lands, Pacific Northwest states, 1969–1993.




USDI Public Land Statistics: (1970-1994)

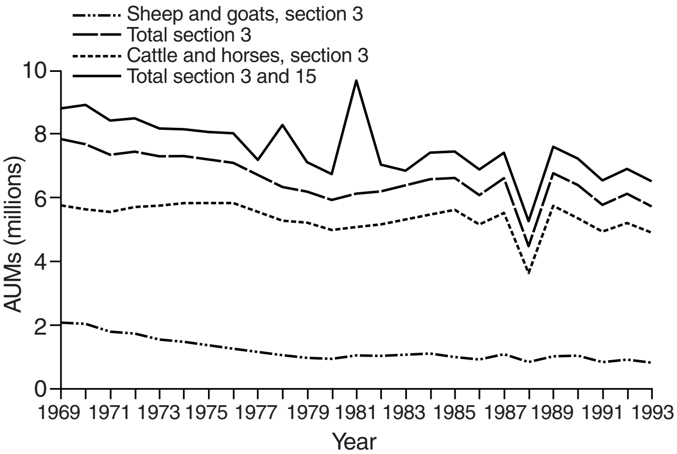
**Fig. 4.17**—Livestock grazing use of Bureau of Land Management lands, California, 1969–1993.

was the sum of all animals permitted to graze, both expressed in AUM's (FSM 2231.41). Authorized use can differ from permitted use for a number of reasons known before the grazing season commences that affect the available forage supply, and is usually less than permitted use. Examples include a drought the preceding year and restrictions resulting from logging or reforestation.

Increasing non-use, as described by Joyce (1989), probably does not reflect a general economic decline in the agriculture sector. Such a decline would more likely be expressed in terms of falling livestock numbers actually permitted to graze on NFS lands. There are provisions to adjust permitted livestock numbers to ensure proper use of the forage resource and/or to comply with forest management plans, laws, regulations, and policy (FSM 2231.6).

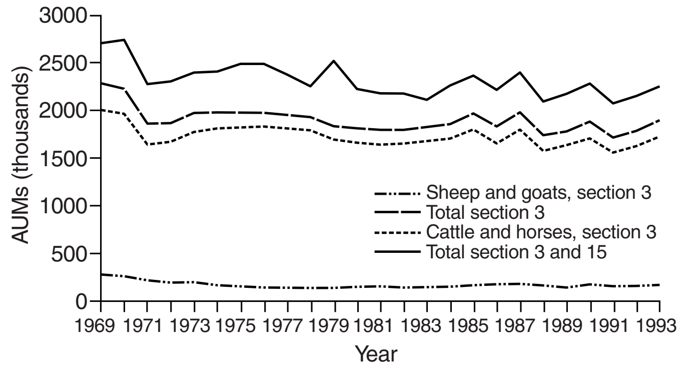
Joyce's (1989) definition of non-use differs from that depicted under FSH 2231.7 which allows an individual permittee or the Forest Service to temporarily withhold grazing on an allotment for permittee convenience, resource protection, or range research purposes. For this Assessment, I have continued portraying non-use following Joyce's definition.

In the last rangeland assessment document, Joyce (1989) reported that non-use of cattle allotments was increasing even though permitted use had remained constant. Percentage non-use of sheep allotments exceeded that for cattle, but had remained reasonably constant



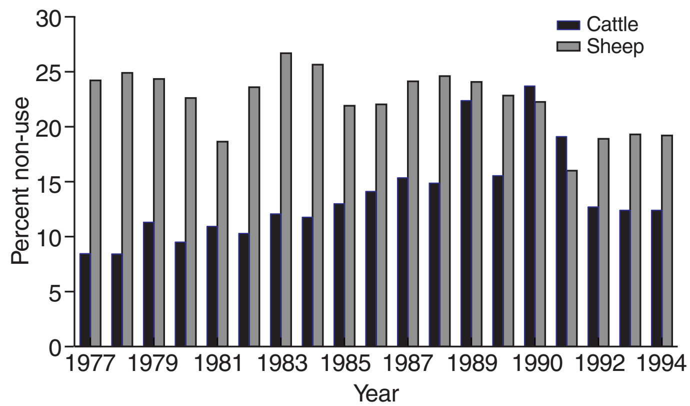

USDI Public Land Statistics: (1970-1994)

**Fig. 4.18**—Livestock grazing use of Bureau of Land Management lands, Intermountain and Rocky Mountain states, 1969–1993.




USDI Public Land Statistics: (1970-1994)

**Fig. 4.19**—Livestock grazing use of Bureau of Land Management lands, Arizona and New Mexico, 1969–1993.




Source: USDA Forest Service, Grazing Statistical Summary: 1978-1995 Note -- Non-use = [ 1 - (actually grazed/paid authorized use)

**Fig. 4.20**—Non-use of cattle and sheep permitted use on National Forest System Lands. Note: Non-use is defined as the proportion of permitted livestock use, expressed in AUM's, not authorized by annual operating plans: 1. – (authorized AUM's/ permitted AUM's). See Joyce (1989).

during the same period. After adding annual statistics for 10 more years (1987–96), it is becoming evident that the proportion of authorized to permitted cattle is not showing long-term increases but has remained variably steady between 10 and 15 percent since the early 1980's. The proportion was higher in 1988, 1990, and 1991 for some reason. Sheep non-use has ranged between 19 and 25 percent during the past 20 years, and also shows no long-term trend (figure 4.20).

# Consumption of Red Meat

## Domestic Consumption

Demand for red meat may act as a useful indicator for grazing land productive capacity because it has a direct bearing on national livestock numbers. Total per capita consumption of beef/veal, pork, poultry, fish, and lamb combined has very slowly increased since the early 1980's. The same trend noted by Joyce (1989) in the last assessment has continued. If this trend continues, Americans will soon be eating more than 200 lb. of meat per year. The increase in per capita meat consumption is due to rising use of poultry in U.S. diets. Statistics from USDA National Agricultural Statistics Service (1999) show annual per capita poultry consumption going from 32.9 lb. in 1975 to 65.8 lb. in 1998 (figure 4.21).

In 1995 and 1996, the National Agricultural Statistics Service reported average annual per capita consumption of beef and veal in boneless, trimmed meat equivalents as 64 lb., the same as it was in 1990 (USDA National Agricultural Statistics Service 1999). Thus, beef/veal consumption continues to be level.

With individual red meat consumption at a constant level, increases in domestic consumption will primarily be a function of population increases. Even these increases are projected to be fairly small over the next 20 years, particularly in comparison to expected growth in meat consumption within developing countries (table 4.2).

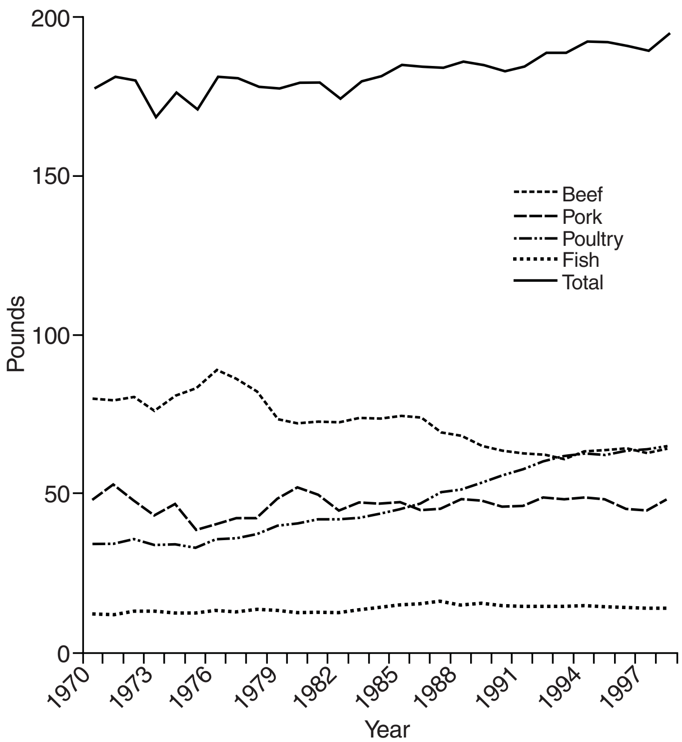



**Fig. 4.21—**Per capita consumption of beef and veal, pork, lamb and poultry in the United States, 1975 to 1991. Note: Total meat consumption includes veal, lamb, and mutton. (Frazão 1999).

## Meat Exports and Imports

In 1970, meat imports exceeded exports by more than an order of magnitude. Beef imports added to 813,000 metric tons while beef exports were only 46,000 metric tons. Between then and the time of the last Assessment (Joyce 1989), meat imports increased slightly, but exports expanded more than five-fold. Beef imports and exports were 1.03 million metric tons and 274,000 metric tons, respectively (USDA Economic Research Service 1989).

According to USDA-ERS (Interagency Agricultural Projections Committee 1998), the short-term trend of expanding beef exports will be delayed until weak demand in the Pacific Rim recovers and the U.S. cattle inventory builds to higher levels. How the world beef trade will adjust to the more open markets created by GATT is far from certain. Long-term growth in beef demand in the Pacific Rim may be slower than previously anticipated, however (Interagency Agricultural Projections Committee 1998). Regardless, the U.S. continues to be the principal source of high-quality fed beef for export, and the Pacific Rim will provide the largest market for these meats.

**Table 4.2—**Projected changes (percent) in total meat consumption in the developing and developed countries, 1990-2020.

| Product | Developed Countries | Developing Countries |
|---|---|---|
| Beef, other ruminant meat | 11 to 14 | 101 to 170 |
| Pork | 12 to 16 | 131 to 225 |
| Poultry | 30 to 31 | 126 to 211 |

*From Sere and Steinfeld (1996)*

# Conclusions

The productive capacity of U.S. rangelands will not likely change significantly in the near future. The expected slow decline in the grazing land base may be offset, in part, by equally slow increases in rangeland health and advances in grazing technology. Projected slowly rising consumption of red meat should not create extensive new demands for forage. For that and other reasons, lands in the Conservation Reserve Program, described in chapter 2, are not expected to have even a moderate effect on livestock numbers. They have been shown to have a positive influence on some wildlife species at the regional level, however, including the provision for feeding cover. A proliferation of non-indigenous weeds, explained in chapter 3, Rangeland Health, could feasibly impact the productive capacity of rangeland, regionally. If demands for forage ever exceed supply, however, market forces should prompt shifts in land use from agriculture to grazing land, such as described in chapter 2, Extent of Rangelands.

Since there is no reason to expect significant increases in the rangeland base, advances in technology affecting productivity of rangeland forage species, or restoration of rangeland health, we must conclude that the supply of forage in the United States is not likely to change significantly over the next few decades. The country's productive capacity should remain adequate to promote sustainable management of U.S. rangelands, however.

# Chapter 5: Institutional Framework for Rangeland Conservation and Sustainable Management

Criterion 7 of the Montreal Process pertains to a country's overall policy framework that can facilitate the conservation and sustainable management of forests. Because 20 of the 67 total Montreal Process indicators are under Criterion 7, they have been clustered into five sub-criteria. Applied to rangelands, these sub-criteria are: The extent to which the (1) legal framework, (2) institutional framework, and (3) economic framework support the conservation and sustainable management of rangelands; (4) the capacity to measure and monitor changes in the conservation and sustainable management of rangelands; and (5) the capacity to conduct and apply research and development aimed at improving rangeland management delivery of rangeland-derived goods and services (USDA Forest Service 1997).

The legal framework was succinctly discussed in Chapter 1. In the latter half of the 20th Century, numerous laws promoting various conservation practices, including public involvement in federal land management planning, have been written into U.S. law (table 1.3). Conservation and stewardship provisions included in various farm bills have added to the legal framework for sustainable management.

The institutional framework for sustainable rangeland management at a national scale focuses, among other things, upon providing for public involvement activities, undertaking periodic planning, assessment and policy reviews, and developing and maintaining human resource skills across relevant disciplines. The purpose here is to address this last indicator, maintaining a critical mass of people with adequate technical skills to properly manage rangelands and to conduct needed research and development.

## Rangeland Science Education

The education of students in rangeland management and related disciplines at the undergraduate level has undergone a transformation since the 1980's, principally in response to two factors: (1) Advances in ecology and management applications and (2) changing employment opportunities for graduates.

For the 40-year period ending in the late 1980's, most range management students took courses emphasizing a triad of plant, soil, and animal sciences. The principal job opportunity for those with an undergraduate degree was as a range conservationist with the federal government.

**Table 5.1**—Names of university departments offering a range management degree in the United States. Number in parentheses indicates more than one university with the same name. From Kothmann (2000).

| Offering Ph.D. Degree | Not offering Ph.D. Degree |
|---|---|
| Rangeland Resources (2)[1] | Agriculture |
| Rangeland Ecology and Management[1] | Agribusiness, Agronomy, Horticulture and Range Management |
| Rangeland Ecosystem Science[1] | |
| Agronomy (2) | Animal and Range Sciences (2) |
| Animal and Range Sciences (2) | Animal and Wildlife Sciences |
| Botany and Range | Natural Resource Management |
| Environmental Sciences, Policy & Management | Rangeland Resources and Wildland Soils |
| Plant and Soil Sciences | |

[1] *Four largest departments*

As stipulated by law, public rangelands were (and are) managed under a multiple-use, sustained-yield concept for grazing livestock, wildlife habitat, recreation, water, and timber production. Doctoral students often found employment with teaching and research universities after graduation. Following far behind were careers managing ranches and working for consulting companies.

In the 1990's, both the job market and undergraduate curriculum began to change. Working for regulating agencies, environmental organizations, and companies specializing in rangeland restoration became a much more promising career choice (Personal communication, Dr. R. Dennis Child, Colorado State University, Fort Collins). Employment as a rangeland conservationist with federal land management agencies started to involve new skills. The planning process has taken on an increasingly important role in rangeland management. It now must provide for alternative actions, be developed on a multi-resource basis, and include public involvement. Consequently, curricula have also diversified and now incorporate such subjects as ecosystem/sustainable management, landscape ecology, biodiversity, restoration ecology, and rangeland planning (Kothmann 2000).

Department names have changed to reflect the new science of rangelands (Kothmann 2000). The four largest

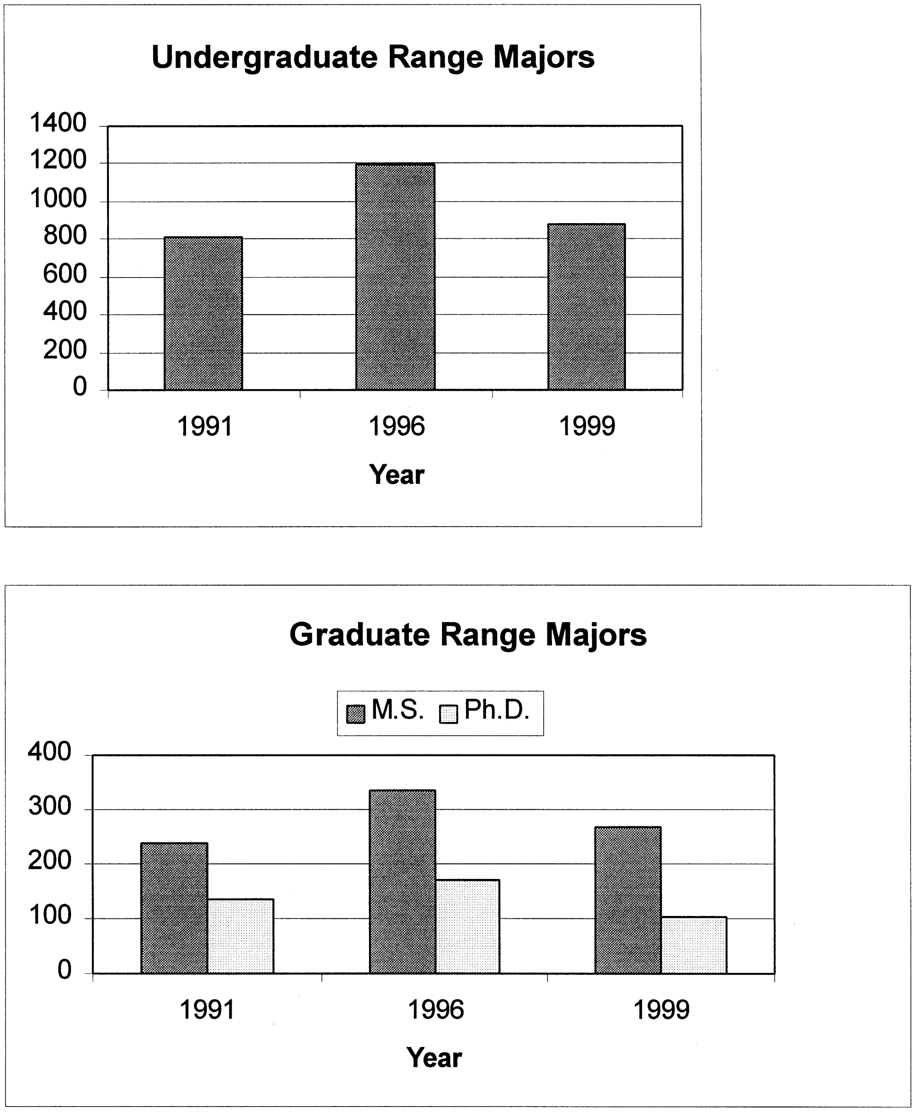



**Fig. 5.1—**Number of undergraduate (A) and graduate (B) range science majors, 1991, 1996, and 1999 (from Kothmann 2000).

university departments all have the word "rangeland" instead of "range," in them (Table 5.1). In addition, a broad range of concentration areas are offered within undergraduate degree programs. Range and Forest Management, Rangeland Ecology, and Restoration Ecology can now be found in the Colorado State University General Catalog, for example.

Trends in student numbers have been mixed during the 1990's. Annual enrollments at the B.S., M.S., and Ph.D. levels collectively increased about 25 to 30 percent between 1991 and 1996. Since then, enrollments have been dropping (figure 5.1). Although more undergraduates were enrolled in rangeland-related curricula at the end of the last decade than at the beginning, nearly all of the increase can be attributed to smaller universities in the Southern Assessment Region (Texas) that stress teaching over research. Numbers of students training to be researchers, particularly Ph.D. candidates, showed a downward trend during the latter 1990's (Kothmann 2000), but no long-term prognoses are possible from these data, alone. It is likely that student numbers are holding somewhat constant because of the more diverse employment opportunities mentioned above.

The number of rangeland science faculty members, expressed as full-time equivalents (FTE), has remained exceptionally constant through the 1990's. Teaching positions have held within a narrow range of 58 to 62 FTE's between 1991 and 1999, and positions devoted to research have varied between 59 and 69 FTE's with no apparent trend. During the same time period, faculty allocations

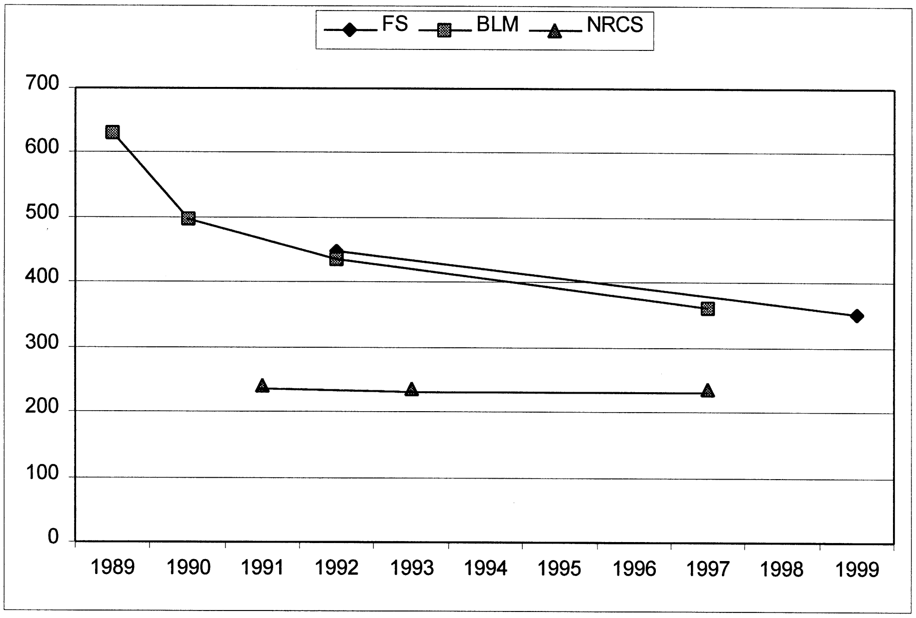



**Fig. 5.2**—Trends in the number of permanently-employed rangeland conservationists working for the USDA Forest Service, USDA Natural Resource Conservation Service, and USDI Bureau of Land Management, 1989–1999. From unpublished data.

for rangeland extension actually increased from 34 to 44 FTE's (Kothmann 2000).

There is no information on a possible "aging" effect upon the population size of university faculties of rangeland science. However, if a substantial proportion of faculties are approaching retirement, the outlook for continued stability is not favorable unless university administrators replace retiring faculty members with others in disciplines related to rangeland science or management. Informal discussions with heads of rangeland science departments indicates that, at best, only a fraction of retirees will be replaced during the foreseeable future. An emerging trend within natural resource academia of splitting FTE's into multiple departments (replacing a retiring professor with someone who is part-time in another department) may moderate any net losses of rangeland science faculty.

## Trends in Persons Employed in Rangeland Management

Employment trends of rangeland conservationists in the three principal Federal land management agencies—Forest Service (FS), Bureau of Land Management (BLM), and Natural Resources Conservation Service (NRCS)—depict two different patterns, one holding steady and one a constant decline (figure 5.2). The number of rangeland conservationists in the FS dropped by 21 percent between September 1992 and May 1999. Losses were not evenly split across FS regions. The Intermountain Region lost 48 positions (40 percent), while the Eastern Region gained one position (100%). All FS regions have identified current and future staffing shortages of rangeland conservationists (Unpublished report, National Academy of Public Administration, Washington DC). During a roughly comparable time, 1990 to 1997, the BLM lost 137 rangeland conservationist positions, a decrease of 28 percent (Unpublished data, USDI Bureau of Land Management, Washington DC).

One reason for declining numbers of rangeland conservationists within the FS is the recent tendency to classify positions so that individuals can supervise or be responsible for two or more different specialties. This policy has dramatically expanded the number of general biologist positions within the FS because a general biologist can supervise foresters, wildlife biologists, soil scientists, and rangeland conservationists (Unpublished report, National Academy of Public Administration, Washington DC). Effects of classification have impacted the number of forester positions much more than rangeland conservationist positions.

An expansion in the number jobs performed by each forest staff member, following agency downsizing, has resulted in an erosion of career ladders in several natural resource management disciplines, including rangeland conservation. Slowing the rate of advancement has been seen to also adversely affect the number of positions filled by individuals in the rangeland conservationist job series (USDA Forest Service, Range Management Staff 1990).

Unlike the FS and BLM, the NRCS has maintained a nearly constant workforce of rangeland conservationists throughout the 1990's (figure 5.2). There are several possible interrelated reasons for such a disparity. The NRCS mission has broad support from state and local organizations such as the National Association of Conservation Districts and the Grazing Lands Forum (personal communication, Mr. Dennis Thompson, National Rangeland Conservationist, NRCS). It is feasible that the workload associated with conservation programs in recent Farm Bills has been deemed important enough by policymakers to provide expanding budgets for rangeland conservation.

Within the Federal land management agencies, reduced hiring has contributed to an increased workforce average age. Between September 1992 and May 1999, the average age of FS permanent employees jumped by three years, from 42.6 to 45.6 years. The number of rangeland conservationists eligible for retirement will rise from 4 percent of the permanent staff in 1999 to 19 percent in 2004 if present hiring and retention trends continue (Unpublished report, National Academy of Public Administration, Washington DC). An aging workforce adds uncertainty to any outlook of how adequately our Nation will maintain a critical mass of people with needed technical skills to properly manage rangelands.

The loss of people with adequate resource skills in rangeland conservation has, in part, induced the Society for Range Management to create a certification process for rangeland managers. The Society was concerned that people planning and implementing management practices on rangelands increasingly lack basic qualifications needed to conduct professional work. According to procedures put forth by the Society for Range Management, certified professionals should have training and experience in the areas of vegetation and animal management, planning and policy, measurement and assessment, and communications (see: <http://www.srm.org/procedures.html>).

Work in research and development is an important component of any technical discipline, including natural resource management. In the United States, the preponderance of rangeland-related research is conducted by universities and their associated state experiment stations, FS research stations, and USDA Agricultural Research Service. Non-governmental organizations, such as The Nature Conservancy, and other state natural resource-related organizations also carry out some range research. University professors are responsible for nearly all research conducted under the auspices of universities, and information about their numbers were discussed earlier.

In the FS, a significant shift has occurred within the biological sciences—a shift away from research foresters and rangeland scientists and towards ecology and wildlife biology (Unpublished report, National Academy of Public Administration, Washington DC). Between 1985 and 1999, the number of rangeland scientists decreased from 3.3 percent to 1.0 percent of the agency's research and development workforce. Many of the remaining rangeland scientists are approaching retirement age (personal communication, Craig Whittekiend, Society for Range Management, Denver, CO). Thus, given the redirection of FS R&D resources since 1985, it is not implausible to expect future rangeland research to focus upon hypotheses related to species, community, and ecosystem sustainability. This work will necessarily be undertaken by scientists with training, skills, and interests in disciplines represented by the existing FS R&D workforce.

To conclude, new approaches are needed to assess how well the United States promotes programs that maintain human resource skills across relevant disciplines supporting the sustainable management of rangelands. They must be able to capture the degree of professional rangeland management, along with support for rangeland research, at a time when career paths are not clearly defined, science is creating previously unidentified disciplines related to monitoring and assessments, and ideas about what constitutes sustainable management is becoming more complex, reflecting the diverse values corresponding with our American society.

An understanding of other social, economic, and political indicators, as expressed in Criteria 6 and 7 of the Montreal Process, will also assist future national assessments of U.S. rangelands.

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United States Department of Agriculture

Forest Service
Rocky Mountain Research Station

General Technical Report RMRS-GTR-68
December 2000