CHAPTER

1

Pastureland and Hayland in the USA: Land Resources, Conservation Practices, and Ecosystem Services

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The total economic value of forage and grasslands that support ruminant animal production is estimated at about $45 billion annually. Photo: USDA.

Forage, grasslands, and grazing lands constitute more than two-thirds of all agricultural land in the USA. Indeed, some view these lands as "the cornerstone of all agriculture" (Wedin and Fales, 2009). Pasture and hayland account for 73 million ha in the USA (Figs. 1.1 and 1.2) and provide several ecosystem goods and services. Increasing and sustaining these ecosystem goods and services (e.g., conserving and protecting soil, water, and air resources) usually requires the investment of public resources. Government agencies increasingly are tasked to account for money invested in conservation policies, programs, and practices in quantitative terms of environmental outcomes (e.g., how much has water quality or soil quality been improved?) rather than simple numeric metrics (e.g., kilometers of fence installed, hectares of land treated). Although not perfected, there are methods being developed and evaluated to quantify the outcome in monetary values (Brookshire et al., 2010).

The Conservation Effects Assessment Project (CEAP) is a multiagency effort to quantify scientifically the environmental outcomes of conservation practices used by private landowners that are supported by U.S. Department of Agriculture (USDA) and other conservation programs (Duriancik et al., 2008). The purpose of CEAP is to "help policy makers and program managers implement existing and design new conservation programs to more effectively and efficiently meet the goals of U.S. Congress and the Administration" (James and Cox, 2008). Outcomes from CEAP will also inform scientists and practitioners of policy needs and expectations of policy makers to account for the ecosystem services and environmental outcomes intended by specific conservation practices. In addition, CEAP will shed light on gaps in scientific knowledge needed to support conservation outcomes and provide insight as to how to attack researchable problems regarding these practices.

Principal components of CEAP include 1) a national assessment of conservation practices, 2) studies of conservation practices up to the watershed level, and 3) detailed bibliographies and syntheses of scientific literature regarding environmental outcomes of specific conservation practices. Assessments were conducted within three main agroecological resource areas: croplands, wetlands, and grazing lands, including effects on wildlife in each. These assessments contribute to determining the effectiveness of current programs and the process of building the science base for conservation, which includes research, monitoring and data collection, and modeling (Duriancik et al., 2008).

Earlier CEAP literature syntheses focused on cropland and wildlife. The cropland synthesis documented the environmental outcomes of soil, water, nutrient, and pest management conservation practices applied to rain-fed and irrigated cropland (Schnepf and Cox, 2006). A follow-up literature synthesis focused on multidisciplinary analyses of achieving realistic cropland conservation goals at watershed and landscape scales (Schnepf and Cox, 2007). The wildlife synthesis focused on the Conservation Reserve Program (CRP) and its resultant effects on fish and wildlife (Haufler, 2005, 2007).

Because most CRP land is grassland, the conclusions and recommendations from the wildlife syntheses are particularly relevant to managed forage and grasslands. For example, grassland managed for the CRP has benefited grassland birds, especially in the Great Plains (Johnson, 2005). Grassland in CRP, however, often is cut one or two times for weed control, but not harvested (except for hay during drought emergencies), which differs in timing of cutting and residue management from normal pasture and hayland practices. This difference restricts direct transfer of management

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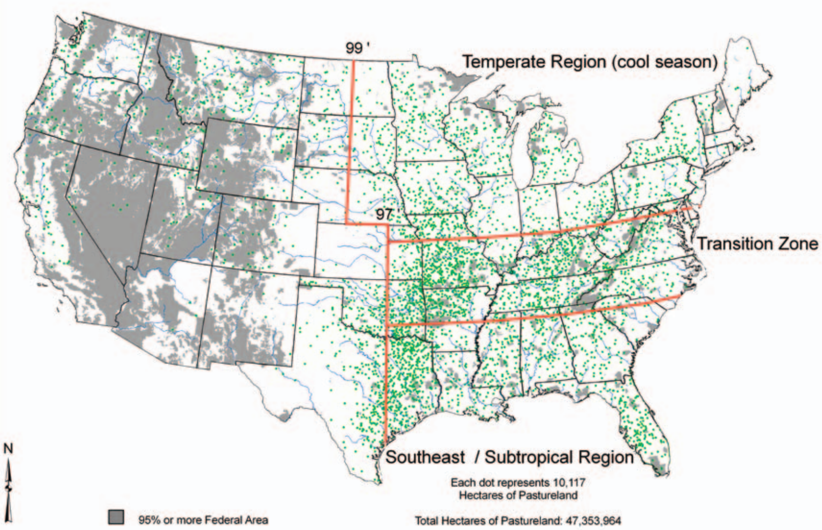

FIGURE 1.1. Area of pastureland in different regions of the USA. See Table 1 for states grouped into the temperate (cool season) region, transition zone, and the southeast and subtropical regions. Source: USDA-NRCS (2003).

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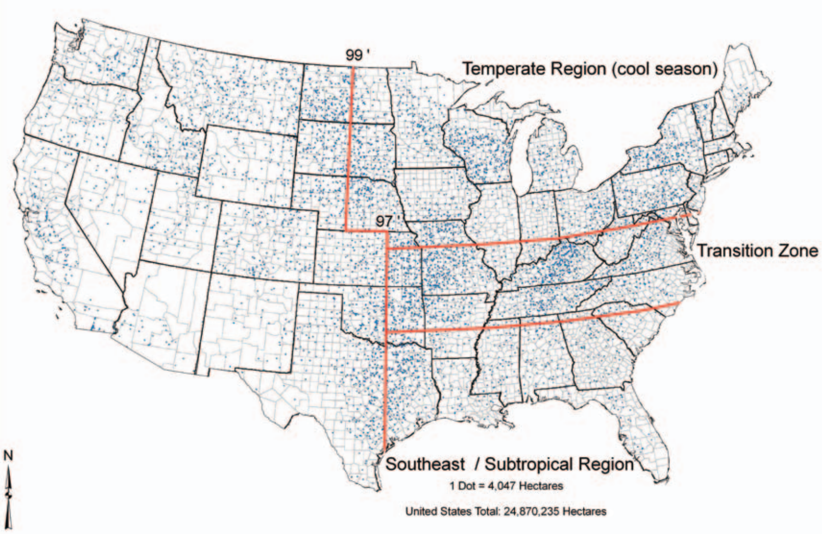

FIGURE 1.2. Area of forage/hayland in different regions of the USA. Source: USDA-NASS (2009).

effects on ecosystem services from CRP land to hay and pasture areas.

In this literature synthesis, individual chapters address four USDA–National Resources Conservation Service conservation practices: forage and biomass planting (practice standard 512; formerly pasture and hayland planting), prescribed grazing (practice standard 528), forage harvest management (practice standard 511), and nutrient management (practice standard 590). As a prelude to the chapters on individual conservation practices, in this chapter we describe pasture and hayland resources in the USA, including national trends; touch on the history of conservation practices on pasture and hayland; and introduce key conservation challenges on pasture and hayland.

PASTURE AND HAYLAND: EXTENT AND VALUE

Pastureland is "land devoted to the production of indigenous or introduced forage for harvest by grazing, cutting, or both" (Allen et al., 2011). There are 48.5 million ha of pastureland in the USA (Fig. 1.1) and 25.1 million ha of land used for production of hay and other conserved forage (except row crops for silage) (Fig. 1.2; USDA–National Agricultural Statistics Service [NASS], 2009). Pastureland is concentrated in the humid eastern half of the USA (east of 99° longitude; Vough, 1990; Barnes and Nelson, 2003), whereas land for production of hay and other conserved forage is distributed more broadly across the USA (Figs. 1.1 and 1.2). In addition, there are about 1 million ha of irrigated pastureland in the western USA. Alaska has 4000 ha of pastureland and 8100 ha of hayland. Hawaii has 15,000 ha of pastureland, and Puerto Rico has 70,000 ha.

Cool-season temperate forage and grasslands occupy much of the northeastern USA, the lake states, midwest, and parts of the northern Great Plains. This includes the traditional dairy regions of the upper midwest and the northeast, along with significant production of beef cattle with lesser production of small ruminants (sheep and goats) and horses. Cool-season perennial forages such as orchardgrass (scientific names of all plant species used in this chapter are given in Appendix III), alfalfa, smooth bromegrass, and white clover predominate in this region. Moving southward, the vegetation changes to include more warm-season species in an area often referred to as the transition zone between the cool-temperate and subtropical grassland regions. This zone includes the tall fescue belt, with about 10 million ha of tall fescue that is often overseeded with red clover and managed

TABLE 1.1. Number of grazing livestock in states within climatic regions of the eastern USA. (USDA-NASS, 2009).

State	Cattle and calves	Horses and ponies	Sheep and lambs	Goats
Temperate (cool-season) region				
Connecticut	50,200	11,500	5800	4600
Illinois	1,231,000	79,500	52,400	33,700
Indiana	875,400	81,200	49,000	47,100
Iowa	3,982,000	71,200	209,300	56,000
Maine	88,200	12,200	10,900	5900
Massachusetts	46,800	20,600	11,800	8200
Michigan	1,048,200	101,100	81,700	27,800
Minnesota	2,395,200	90,100	144,600	36,800
Nebraska[1]	3,342,000	33,500	52,700	15,000
New Hampshire	36,900	9900	7700	3900
New Jersey	38,200	30,100	14,800	10,600
New York	1,443,300	85,000	63,200	39,900
North Dakota[1]	674,000	16,800	39,000	1500
Ohio	1,272,400	119,200	123,200	69,500
Pennsylvania	1,609,100	116,300	96,900	59,200
Rhode Island	5100	3500	1500	700
South Dakota[1]	2,570,000	35,600	200,400	4500
Vermont	264,800	13,300	13,900	6600
Wisconsin	3,373,900	120,000	89,600	55,900
Region total	24,346,700	1,050,600	1,268,400	487,400
Transition zone				
Arkansas	1,802,600	79,000	15,300	50,600
Delaware	21,000	4000	900	3500
Kansas[2]	3,335,000	71,300	60,700	27,400
Kentucky	2,395,400	175,500	37,000	98,200
Maryland	190,500	30,700	22,100	16,900
Missouri	4,292,700	149,200	77,000	96,400
North Carolina	820,200	78,400	27,700	98,400
Oklahoma[2]	1,680,000	127,600	51,500	61,500
Tennessee	2,122,000	142,000	29,800	131,000
Virginia	1,566,200	90,400	77,600	63,100
West Virginia	411,000	37,700	38,300	27,900
Region total	18,636,600	985,800	437,900	543,900
Southeast/subtropical region				
Alabama	1,187,200	87,100	16,900	80,400
Georgia	1,117,100	76,700	11,300	84,000
Louisiana	878,700	60,500	8700	21,600
Mississippi	987,300	65,300	8400	30,600
Florida	1,711,000	120,600	13,000	57,700
South Carolina	401,000	43,300	7900	43,900
Texas[2]	5,110,000	231,000	60,700	365,000
Region total	11,392,300	684,500	126,900	683,200
Eastern U.S. total	54,375,600	2,720,900	1,833,200	1,714,500
Contiguous U.S. total	96,347,900	4,028,800	5,812,200	3,140,500

[1]Data from counties east of the 99th meridian. [2]Data from counties east of the 97th meridian.

“CEAP will shed light on gaps in scientific knowledge”

“In contrast with rangeland, pastureland management is relatively intensive and technology based”

mainly for beef cattle production. The southeastern region (along with Hawaii and Puerto Rico) relies heavily on warm-season grasses such as bermudagrass and bahiagrass, along with cool-season annual legumes and grasses (e.g., arrowleaf clover and annual ryegrass) to fill forage gaps in autumn and winter.

Of the 109 million head of livestock that utilize forage and grazing land in the USA, about 61 million head are in the eastern half (Table 1.1). Approximately 45% of these eastern livestock are in the cool-temperate region, 34% in the transition zone, and 21% in the southeast and subtropical region. Alaska, Hawaii, and Puerto Rico account for about 400,000 head of grazing livestock.

In contrast with rangeland, pastureland management is relatively intensive and technology based, commonly with inputs of seeds, fertilizers, and pesticides. Most plant species present are not native, and pastureland may be periodically renovated or replanted by a variety of techniques. Stocking densities on pastureland vary from 0.7 to 2 ha per grazing animal (Burns and Bagley, 1996). By contrast, rangelands predominate in the drier western half of the USA, with a few exceptions such as the flatwoods rangeland of Florida, longleaf pine grassland in Alabama and Louisiana, and scattered areas of fragmented native grasslands.

The traditional goods from forage and grazing lands include food, feed, fiber, forest products, milk, and meat. The total economic value of forage and grasslands used in ruminant animal production is estimated at about $44 billion (Table 1.2). Hay and other conserved forage production account for $18 billion of farm income (USDA-NASS, 2009). In addition, there are numerous ecosystem services provided by forage and grazing lands, including reduced soil erosion and improvements in water quality, wildlife habitat, and air quality. There often is little or no direct economic return to the land manager, yet society is rapidly recognizing that the intrinsic values of these ecosystem services are important for the public good and that there is a need for them to be provided.

NATIONAL TRENDS IN FORAGE AND GRAZING LANDS

The estimated 238 million ha of permanent grassland pasture and rangeland account for 26% of all U.S. land and half of the agricultural land (Lubowski et al., 2006). Adding cropland used as pasture (25 million ha), woodland grazing land (54 million ha), and that harvested for conserved forage (25 million ha) to the permanent grassland area indicates total forage and grazing land equals about 342 million ha, or 38% of the total U.S. land area and more than two-thirds of all agricultural land (Lubowski et al., 2006). This total does not include land grazed before or after crops were harvested.

About 7% of the total permanent grassland pasture and rangeland is in the eastern half of the USA (Fig. 1.3). In the humid south, cropland pasture and forested grazing predominate. Nationwide, grazed woodland includes open-canopy forest, land reverting to forest, and other woodlands that contain grazable grass or other forage. Grazable woodlands dominate parts of the humid south as a function of productivity potential, demand for grazing land, understory species composition during expansive growth

TABLE 1.2. Forage value in livestock diets in the USA. Adapted to 2008 cash receipts from Barnes and Nelson (2003).

Animal type	Feed costs as a proportion of receipts	Proportion of feed units fed as forage	Forage value as proportion of feed costs[1]	2008 cash receipts[2]	Forage value[3]
				Billions of dollars	
Beef cattle	0.70	0.83	0.581	48.2	28.0
Sheep+wool	0.70	0.91	0.637	0.45	0.29
Dairy cattle (milk)	0.50	0.61	0.305	34.8	10.6
Horses[4]	0.7	0.6	0.42	11.8	5.0
Goats	0.7	0.9	0.63	0.25	0.16
Total forage value					44.0

[1]Calculated as column 2 multiplied by column 3. [2]USDA-NASS (2009). [3]Calculated as 2008 cash receipts (column 5) multiplied by value in column 4. [4]American Horse Council (available at http://www.horsecouncil.org/nationaleconomics.php [verified 24 Jan. 2011]).

of the trees, and density of overstory. On the southern and southeastern coastal plains woodland values are enhanced by grazing open stands of pine almost year-round in many climatic regimes. Upland hardwoods with dense canopies, typically covering the northeast region of the USA, produce less forage; however, these landscapes at times may be grazed.

During 1997–2002, cropland pasture decreased 1%, reducing total grazed area by 2.4 million ha, about a third of this via conversion to CRP land. Approximately 1.6 million ha changed from pasture to forest. Cropland pasture, permanent pasture, and rangeland decreased by 5.3 million ha, which was about 55% of the total loss of 9.7 million ha of agricultural land identified in the National Resources Inventory (USDA-NRCS, 2003). Cropland used for pasture is typically part of a rotation between crop and pasture use, with variable rotation periods. Two-thirds of the 25 million ha of cropland pasture were located in the southern plains, corn belt, northern plains, and Appalachian regions. Much of the cropland pasture in the south and plains states occurs on more marginal lands.

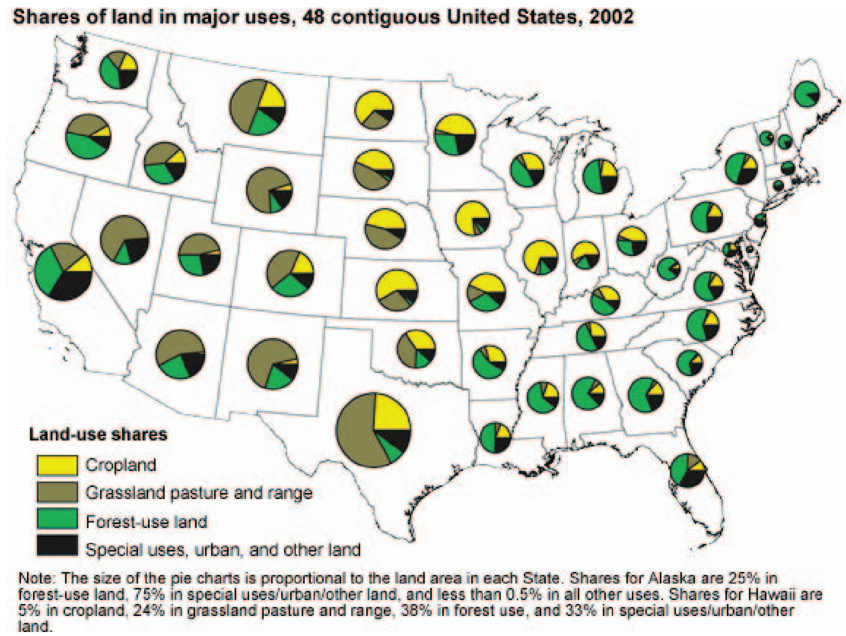

FIGURE 1.3. Proportions of cropland, grassland pasture, and range, forest-use land, and other land in the 48 contiguous states (Lubowski et al., 2006). Used with permission.

Trends in pasture, rangeland, cropland, and woodland used for grazing indicate that total grazing land decreased by about 108.5 million ha (about 25%) from 1945 to 2002 (Lubowski et al., 2006). This land-use change may reflect a transition to urban, recreational, wildlife, and environmental land uses. One exception to the long-term trend is that permanent pastureland increased by 0.8 million ha in the southeastern USA, mostly from land classified previously as grazable woodland. In other parts of the USA, grazable woodlands decreased by nearly 58%. This long decline in grazable woodland might be explained by fewer and larger farms, greater woodland canopy density, and greater efficiencies in both livestock and woodland management. All of these factors have been especially important in the southeastern USA, where high proportions of woodland are grazed (Lubowski et al., 2006).

HISTORY OF CONSERVATION PRACTICES ON PASTURE AND HAYLAND

Water runoff and some associated soil loss from agricultural land have been observed for centuries, but the soil loss was not quantified. But when measured, it was learned that pasture and hayland were much more effective in reducing runoff and associated soil loss than were row crops. Federal conservation practices developed and applied to cropland and to pasture and hayland date back to the 1930s, which paralleled the beginning of government agencies such as the USDA-NRCS (Bennett, 1939; Helms, 1990). Early prescribed practices focused on reducing overgrazing on pasture and rangeland. The theme of grassland agriculture using permanent vegetation as a conservation practice, using hayland in crop rotations, and applying conservation practices to pastures and hayland emerged in the 1930s and runs through several influential college textbooks on pasture and forage management (e.g., Wheeler, 1950; Hughes et al., 1951; Miller, 1984; Barnes et al., 2003, 2007).

Research on conservation practices also dates back to the 1930s with the establishment of soil conservation experiment stations and collaboration between the Soil Conservation Service (progenitor of the USDA-NRCS) and the Bureau of Agricultural Economics (progenitor of the USDA Economic Research Service [ERS]) to assess benefits of conservation practices. Some of this research was documented in early USDA bulletins (e.g., Hoover, 1939; Bennett, 1951; Dale and Brown, 1955). During the 1970s, the Clean Water Act stimulated research on conservation practices to protect water quality.

Despite several decades of improving management on pasture and haylands through use of conservation practices, significant conservation issues remain and new ones have emerged. There are an estimated 30 million ha of pasture and hayland in the USA that would provide greater environmental benefits from some form of conservation treatment, such as prescribed grazing, pasture/hayland planting, and nutrient management (USDA-NRCS, 2004). Conservation practices to protect soil and water resources are a critical part of pasture and hayland management because much of this land is sloping, is classified as marginal for cropland, and has a small margin for error in management (Helms, 1997).

RESOURCE CONCERNS ON PASTURE AND HAYLAND

The principal resource concerns addressed in conservation programs include soil, water, air, plants, animals, and human resources (USDA-NRCS, 2010a). In addition, efficiency of energy use recently has been added to this list of resource concerns because of the costs of energy and the new role of agriculture in producing renewable energy.

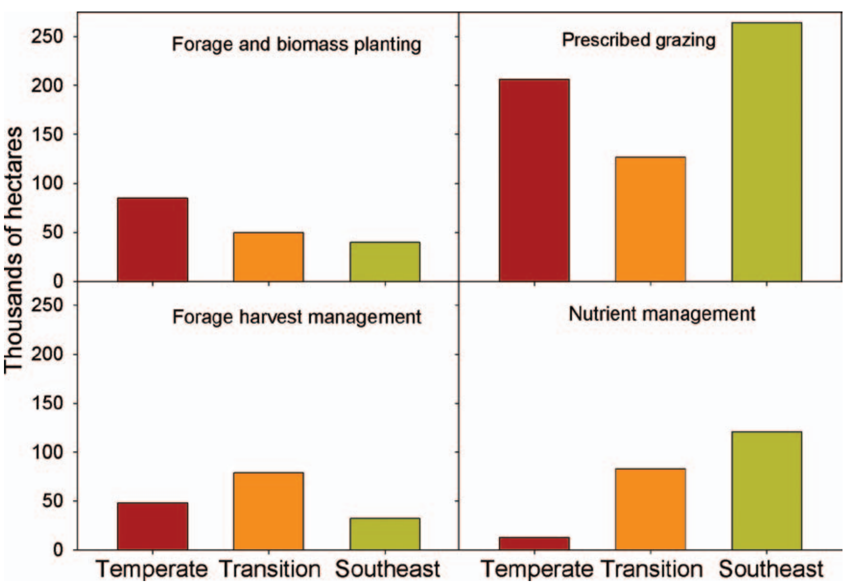

FIGURE 1.4. Pasture and hayland area in three principal regions of the USA to which selected USDA-NRCS conservation practices were applied in 2010. Data for prescribed grazing and nutrient management practices are for pastureland only. Regions are defined in Table 1.1. Data are from the USDA-NRCS performance reporting system.

Mismanagement of pasture and hayland can reduce production and profit and harm the environment. For example, poor nutrient management on pastureland is estimated to contribute 37% of the phosphorus load from the Mississippi river basin into the Gulf of Mexico (Alexander et al., 2008). Grazing management that exceeds sustainable carrying capacity can degrade vegetation, enhance runoff, and impair water quality (Agouridis et al., 2005).

The 2008 Farm Bill outlines several voluntary programs that target resource concerns and conservation on forage and grazing lands, including:

Conservation of Private Grazing Lands (CPGL). Provides technical assistance to owners and managers of private grazing lands to implement grazing land management technologies, protect water quality, and enhance wildlife habitat, among other goals.

Conservation Stewardship Program (CSP). Compensates farmers for undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities.

Farm and Ranch Lands Protection Program (FRPP). Aids local governments and nongovernmental organizations with purchasing conservation easements to protect agricultural use and related conservation values of land.

Grassland Reserve Program (GRP). Protects and restores grassland.

Environmental Quality Incentives Program (EQIP). Provides financial incentives to farmers to promote agricultural production and environmental quality as compatible goals. The program has placed added emphasis on organic production, including assistance for grazing systems.

These programs pay (or provide cost share) farmers to implement various conservation practices to address specific resource concerns. Of the four USDA-NRCS conservation practices addressed in this publication, prescribed grazing was the most widely applied practice during 2010 (Fig. 1.4). Prescribed grazing was applied

Early conservation efforts on grazing lands started during the dust bowl days of the 1930s. Photo: USDA.

to a total of 640,491 ha of pastureland with 41% of that area in the southeast, 32% in the temperate region, 20% in the transition region, and 7% in the western states. The greater application of prescribed grazing in the southeast may indicate that pastures (soils, stands of desired species) are more degraded, the growing season is longer and often year-round, and forage species are better adapted to rotational stocking than in other regions. There may also be more cost-share funding available for a high number of small farms in this region. The forage and biomass planting practice was applied predominantly in the temperate region where legumes are in short rotations and they suffer from winter injury. Forage harvest management was applied mostly in the transition region. The nutrient management practice was applied nearly entirely in the southeast and transition regions, perhaps because of the frequent use of poultry litter and other animal manures on pastures in these regions see (Wood et al., Chapter 5, this volume).

Comparable recent data were not available on the amount of government support for each of

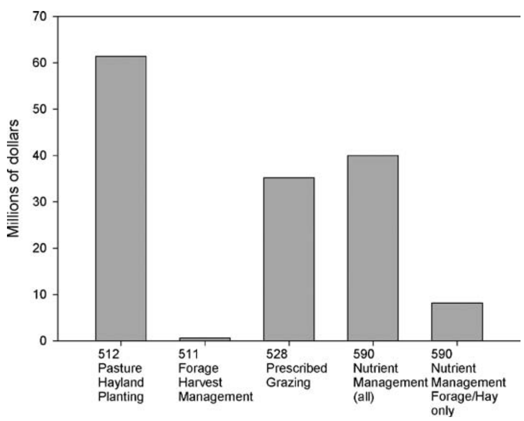

FIGURE 1.5. Government payments made for selected conservation practices implemented in the states east of the Missouri River as part of the Environmental Quality Incentives Program (EQIP). The EQIP program accounts for most of the NRCS conservation practice payments in the eastern USA. Data are totals for the years 2004–2008. Data for 590 nutrient management (all) apply to all classes of livestock and land uses. The data for 590 nutrient management (forage/hay land) apply only to forage and hayland use. Information provided by the Agriculture and Environment Program of Tufts University, Boston, MA.

Hay and other conserved forage production in the USA accounts annually for $18 billion of agricultural receipts. Photo: USDA.

the four practices by region across all NRCS programs. Available information on funding for the Environmental Quality Incentives (EQIP) program during 2004–2008 in the eastern USA, however, shows that most of the funding supported forage and biomass planting (standard 512; formerly pasture and hayland planting; Barker et al., Chapter 2, this volume) and prescribed grazing (Fig. 1.5). Although about $40 million went to nutrient management for all classes of livestock and land uses in the eastern USA, only $8.2 million of that amount could be attributed specifically to forage and hayland use. Only about $500,000 went to forage harvest management.

PRODUCTION CONCERNS ON PASTURE AND HAYLAND

Agriculture in the USA has changed dramatically since the early 20th century, with fewer but larger farms, higher capital costs, and a greater reliance on technology (Sheaffer et al., 2009). Forage and grasslands also are viewed as important sources of biomass feedstock for use in producing renewable energy (Sanderson et al., 2009). Despite these changes, the production concerns of primary interest for pasture and hayland are little changed and include generating adequate amounts of forage of an acceptable nutritive value to sustain various classes of livestock and generate a profit for the farmer. The latter concern is uppermost in the farmer's mind, especially when prices of agricultural outputs are low and volatile.

Adopting and improving grassland management practices can lower production costs and improve the farmer's net income (Sheaffer et al., 2009). Forage yields have increased minimally over the past 50 yr, but there have been small increases in forage quality and improvements in grazing management (Nelson and Burns, 2006). There have also been advancements in reducing stored forage needs for beef cows by extending the grazing season by using deferred grazing, improved nutrient management, and overseeding cool-season species into warm-season pastures in the south.

To achieve production goals, the farmer may replant forage stands with better adapted, more productive, or higher-quality species and varieties; enhance soil fertility through applications of commercial fertilizer or livestock manure; modify the harvest or grazing management to optimize utilization; or control invasive and destructive weeds and pests. Each of these management interventions has implications regarding the soil, water, air, plant, animal, human, and energy resources in the system. For example, renovating pastures or hay fields via tillage may pose soil-erosion risks; poor timing and placement of nutrients from fertilizer or manure may increase runoff or leaching from fields; and intensifying grazing or harvest management may reduce vegetation cover or change the plant community composition. Thus, it is critical that land managers consider how to make conservation practices an integral part of their pastureland and hayland management plan to achieve production and conservation goals simultaneously.

> "it is critical that land managers consider how to make conservation practices an integral part of their pastureland and hayland management plan"

Emerging Emphasis on Ecosystem Services of Pasture and Hayland

Forage and grasslands have long been recognized for multiple services such as soil conservation, water-quality protection, and pleasing aesthetics, among many others (e.g., see USDA, 1948). These multiple services are now recognized in the concepts of *ecosystem functions* and *ecosystem services*, which have received much attention (Daily et al., 1997; Lemaire et al., 2005; Millennium Ecosystem Assessment, 2005). Ecosystem functions are the "habitat, biological, or system properties or processes of ecosystems," whereas ecosystem goods and services include the "benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al., 1997). Ecosystem goods and services have been classified into four main categories: 1) provisioning services, which include products from ecosystems such as food, fiber, and fuel; 2) supporting services, such as primary production and nutrient cycling that enable all other ecosystem services; 3) regulating services such as climate and flood regulation; and 4) cultural services, which include nontangibles such as aesthetic, spiritual, educational, or recreational experiences (Fig. 1.6). These concepts are often discussed in the context of multifunctionality, which refers to the joint production of goods (e.g., agricultural commodities) and ecosystem services (Jordan et al., 2007).

Currently, the USDA-NRCS Conservation Stewardship Program rewards farmers for managing land for multiple ecosystem services, such as soil conservation, water-quality protection, and carbon (C) sequestration (USDA-NRCS, 2010b). The USDA National Organic Standards emphasize pasture utilization not only for feed production but also for animal well-being and product quality (USDA–Agricultural Marketing Service [AMS], 2010). And, the final rule for the Grassland Reserve Program explicitly defines ecosystem services from grasslands as "Functions and values of grasslands and shrublands means ecosystem services provided including: domestic animal productivity, biological productivity, plant and animal richness and diversity and abundance, fish and wildlife habitat (including habitat for pollinators and native insects), water quality and quantity benefits, aesthetics, open space, and recreation" (Federal Register, 2009).

It is clear that forage and grazing lands increasingly are expected to provide ecosystem services beyond the traditional provision of food, feed, and fiber (Sanderson et al., 2009). A partial list of potential ecosystem functions, goods, and services from pastureland is in Table 1.3. Forage and livestock production (provisioning services) provide obvious economic benefits from pasture and hayland (Tables 1.2 and 1.3), along with environmental and social dividends (support, regulatory, and cultural services), such as landscape diversity and open space. Fishing and hunting on these lands provide revenue through sales of licenses, sporting equipment, and access rights while contributing to healthy wildlife populations. In the future, pasture and hayland may supply biofuel feedstocks, leading to reduced greenhouse gas emissions and lesser dependence on fossil fuels. A key feature will be to develop and adopt management systems that optimize the multiple goals to meet priorities of the landowner and the public.

Forage and grazing lands rely on permanent vegetation cover to reduce soil erosion and protect

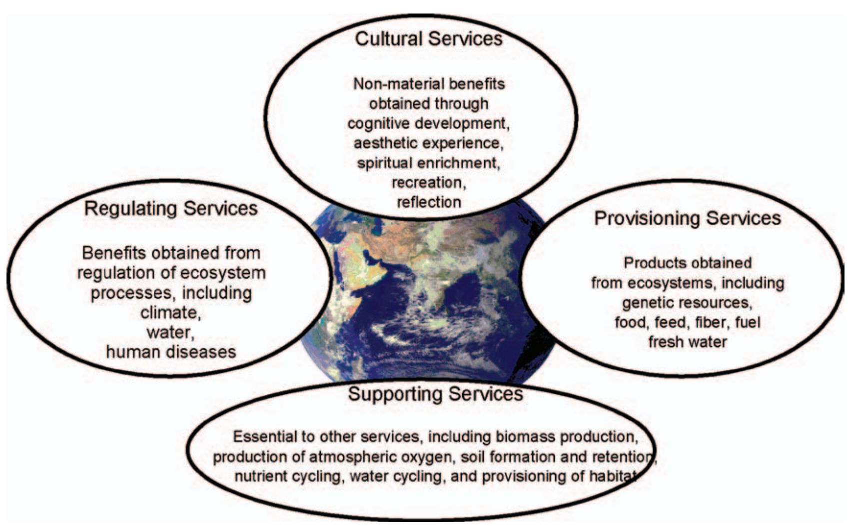

FIGURE 1.6. Main categories of ecosystem goods and services. Graphic courtesy of Alan Franzluebbers, USDA-ARS, Watkinsville, GA. Earth image from NASA Goddard Space Flight Center (http://visibleearth.nasa.gov).

“Social pressures, environmental concerns, and regulations will continue to challenge farmers and ranchers”

TABLE 1.3. Ecosystem goods and services from pasture and hayland and their postulated economic, environmental, and social dividends (adapted from Table 1, pp. 11–13 of the Sustainable Rangelands Roundtable, 2008). The categories of “Economic,” “Environmental,” and “Social/cultural” are somewhat equivalent to the categories of “Provisioning,” “Supporting/Regulating,” and “Cultural” services, respectively, as defined by the Millenium Ecosystem Assessment (2005).

Ecosystem good or service	Dividends		
	Economic	Environmental	Social/cultural
Forage production for livestock	Sale of feed Hay, forage production	Landscapes for biodiversity Clean air and water Carbon sequestration Some plants (e.g., legumes) enrich soil	Open space Rural communities dependent on forage–livestock systems
Livestock production for humans	Sale of meat and fiber products Farming operations Economic base for rural communities	See forage production above Recycling of nutrients	Satisfaction derived from farming as a way of life Serenity of pastoral scenery Open space
Fishing and hunting **Bird watching**	Sales of licenses, gear, guide services Access rights on private or public lands	Promotion of healthy wildlife populations Maintenance of biodiversity Control of hunted populations	Pleasure involved in fishing and hunting Opportunity to observe wildlife
Clean water	Satisfaction of household, agricultural, and industrial needs Sale of bottled water Income from recreation	Quality of aquatic habitat Drinking water for wildlife Rejuvenation of riparian areas	Aesthetics of unpolluted water Pleasure derived from recreation
Biofuel feedstocks	Sale of the feedstock and resulting biofuel	Depending on feedstock: biodiversity maintenance, soil enrichment, carbon sequestration, greenhouse gas mitigation	Reduced dependence on fossil fuels

water quality, support symbioses (e.g., rhizobia and mycorrhizae) to supply some nutrients, and provide an aesthetically pleasing landscape. Grassland systems can also contribute to biodiversity, soil-C storage, and greenhouse-gas mitigation (Krueger et al., 2002). For example, maintaining biodiversity is a desired ecosystem service. Grasslands can be important reservoirs of plants, insects, and other organisms (Pimentel et al., 1992; Sanderson et al., 2004; Jog et al., 2006). Plant species diversity can be exploited to improve grassland production (Soder et al., 2007) and resist weed invasion (Tracy et al., 2004; Sheley and Carpinelli, 2005).

Social pressures, environmental concerns, and regulations will continue to challenge farmers and ranchers to grapple with managing pastures and haylands to provide additional ecosystem services, including biodiversity conservation, C sequestration, mitigation of greenhouse-gas emissions, and bioenergy production (Jordan et al., 2007; Tubiello et al., 2007). These pressures, issues, and regulations have already led society demands for

The permanent vegetation cover on forage and grasslands intercepts rainfall to reduce impact and soil erosion, produces dense roots that hold soil and improve infiltration, filters water, and sequesters carbon in the soil organic matter. Photo: USDA.

a greater public role in agricultural practices for production and land management, and a greater degree of government accountability for resources invested in conservation programs.

The importance of forage and grazing lands in environmental stewardship was emphasized in a national report by the American Forage and Grassland Council (AFGC) that

"The science behind the conservation practices…needs to be assessed."

identified several priority needs related to environmental protection and resource conservation (AFGC, 2001). Among the priorities were innovative grazing systems, flexible and dynamic nutrient management plans, management to increase carbon sequestration, and practices to conserve biodiversity. Thus, the science behind the conservation practices purported to provide these benefits and the magnitude of the ensuing benefits needs to be assessed. The next four chapters provide syntheses of the scientific literature related to forage and biomass planting (practice standard 512; formerly pasture and hayland planting), prescribed grazing (practice standard 528), forage and harvest management (practice standard 511), and nutrient management (practice standard 590).

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