Chapter 3.1 Biological Resources and Agriculture

Biological resources refer to the living landscape—the plants, animals, and other aspects of nature—and are important to society for the various services they provide, as well as problems they may create. Biological resources are grouped into those that affect agriculture, such as cultivated plants, pollinators, and pests; those that are sources of scientific inputs, such as agricultural plant varieties (and their wild relatives) that provide genetic resources; and those that provide natural goods and services, such as wildlife, fish, and scenic beauty. Traditional measures of agricultural productivity do not capture all the benefits of preserving biological resources on private lands. Because of this, private landowners may not have adequate incentives to consider the full range of goods and services produced by the biological resources under their control. In particular, it may not be profitable for farmers to adopt practices that provide the quantity and quality of wildlife habitat and genetic diversity desired by the American public. Similarly, farmers may not consider the full spectrum of indirect benefits when they make land use decisions.

Contents *Page*

What Are Biological Resources?

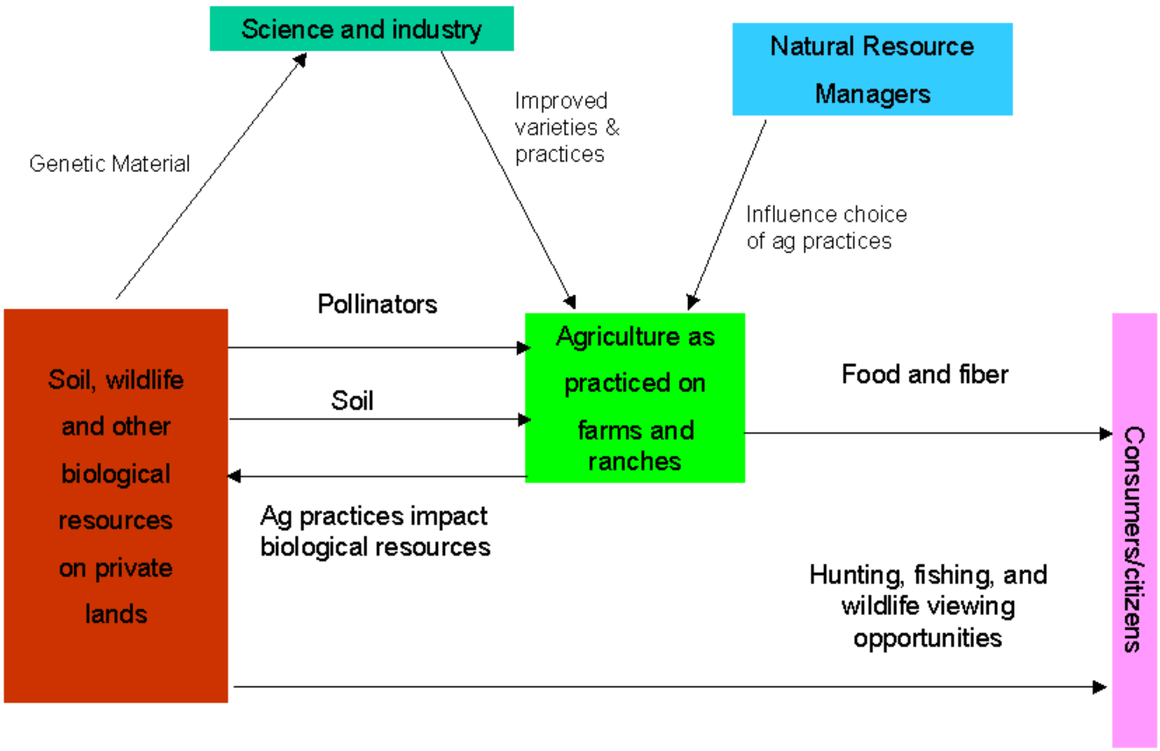
Broadly speaking, biological resources refer to the living landscape—the plants, animals, and other aspects of nature that occur on farmland, forests, and other natural lands. In this chapter, we discuss how private rural lands affect biological resources, and why these effects are important.

Biological resources are important to society for the various services they provide, and for the problems they may create (figure 3.1.1). Biological resources can be grouped into those that affect agriculture, those that are sources of scientific inputs, and those that provide natural goods and services.

Resources that affect agriculture

Examples of such resources include cultivated plants, pollinators, pests, and pest predators. Some biological resources have a direct effect on agriculture. In fact, resources such as soil microbes, agricultural cultivars, and domesticated animals are the foundations of agriculture—they directly contribute to the quantity and quality of food and fiber production. Some biological resources have a less direct effect on agriculture—for better or for worse. For example, noxious weed density on surrounding lands can decrease a farm's profitability because subsequent weed control measures increase costs for the farmer. Similarly, nonagricultural lands can harbor both insect and animal pests (see Chapter 4.3, Pest Management).

Figure 3.1.1—Biological resources, agriculture, and society



Conversely, increased populations of wildlife that eat insects, such as birds and bats, may increase farmland profitabilty as they reduce the need for pest control measures and production costs. Natural pollinators can increase agricultural crop yields. For example, in the 1980s fifty commodities valued in excess of $5 billion (including apples, melons, and almonds) were largely dependent on honeybee pollination (Olmstead and Wotten).

Resources that provide scientific inputs

Examples of such resources include native plants and animals that can provide genetic resources for plant breeding and biotechnology. The natural world serves as an irreplaceable source of biological information, both in terms of macro-structure (ecology) and micro-structure (genetics). Preserving natural landscapes (*in situ* protection) protects the genetic resources and evolutionary processes that are present in nature. Alternatively, some resources, particularly those valued by breeders, can be conserved in gene banks, which hold large collections of diverse genetic resources (*ex situ* protection). Together, these approaches protect plants and animals, and preserve material that may turn out to be useful in the production of new industrial and pharmaceutical products.

Types of Benefits Provided by Natural Goods and Services

Consumptive Benefits *(for example, hunting and fishing)*
The quality of available hunting and fishing depends on (among other things) nature providing the desired species. The quantity and health of these species can be manipulated by land use changes and other human interventions, such as fish stocking, removal of competing predators, and habitat enhancement.

Nonconsumptive Benefits *(for example, wildlife viewing and the enjoyment of natural scenery)*
Unlike hunting, fishing, and other consumptive uses, nonconsumptive uses do not directly impact the environment. For example, viewing wildlife does not directly reduce the quantity of wildlife. As with consumptive uses, the quality of nonconsumptive uses can be either enhanced or diminished through changes in land use and other human interventions. Examples of such interventions include hordes of wildlife viewers trampling a natural environment, or selective plantings leading to an increase in bird populations.

Nonuse Benefits *(for example, ecosystem existence)*
For many, the mere existence of natural ecosystems is important on philosophical and aesthetic grounds. Regardless of the basis for these notions, many people are willing to sacrifice other outputs in order to maintain and protect natural ecosystems. This "existence value" is irrespective of any tangible outputs that may flow from nature. Nonuse benefits do not depend on nonconsumptive uses (such as wildlife viewing). Although nonuse benefits can be augmented through changes in land use and other human intervention, in many cases (such as preservation of a natural ecosystem) the best management is to stop development, control invasive species, and to otherwise "let nature take its course." The Endangered Species Act is an example of a government action that protects nonuse benefits, given that most people will never see or hear most endangered species.

Resources that generate natural goods and services

Examples include wildlife, fish, and scenic beauty present in farmed and natural landscapes. People enjoy a rural landscape's biological resources, particularly the animals and plants that comprise a natural community. Natural goods and services can be divided into three categories based on the type of benefits they supply (see box, Types of Benefits Provided by Natural Goods and Services). Active use of wildlife for activities such as hunting and fishing requires the consumption of biological resources (consumptive benefits). Nonconsumptive activities, such as wildlife viewing, do not directly harm plant and animal populations (nonconsumptive benefits). Finally, many people require no physical connection with the resource to appreciate it. They derive satisfaction from simply knowing that an ecosystem is healthy and will be there for them or their descendants to enjoy (nonuse benefits).

The effects of resources that affect agriculture are partially manifested as changes in readily measurable commodities, such as increased crop yield or reduced production costs. However, many other benefits of biological resources do not accrue to farmers and landowners. In particular, the benefits from *scientific inputs* and *natural goods and services* are rarely measured in terms of changes in the quantity or quality of traditional agricultural commodities. Because of this fact, traditional measures of agricultural productivity do not capture all the benefits of preserving biological resources on private lands.

More importantly, private landowners may not have adequate incentives to consider the full range of goods and services produced by the biological resources under their control. In particular, it may not be profitable for farmers to adopt practices that provide the quantity and quality of wildlife habitat and genetic diversity desired by the American public. Farmers may not consider the full spectrum of indirect benefits, such as pollination services to neighboring farms or potential improvements to plant breeds, when they make land use decisions.

The values of wildlife habitat and genetic resources can be difficult to measure, but there are economic issues in their preservation. We review the importance of wildlife to the American public, examine issues regarding preservation of genetic information both onsite (*in situ*) and offsite (*ex situ*), and discuss how the design of public policies and programs can ensure that biological resources are adequately considered.

Agriculture and Wildlife

Wildlife is important to the American people, and to the U.S. economy (table 3.1.1, and figure 3.1.2). Wildlife-based recreation continues to be popular, with levels of participation in most wildlife-based recreational activities increasing throughout the 1980s and leveling off in the 1990s (Aiken). Although participation rates for recreational hunting and fishing leveled off or declined slightly in recent years, the total number of days spent hunting and fishing (as well as the total expenditures on hunting and fishing) have increased significantly (table 3.1.2). Wildlife viewing participation (nonconsumptive uses) has declined, though some activities have increased. For example, participation in bird watching increased 155 percent between 1982 and 1994 (Cordell et al., 1998).

Expenditures on marketable items, and days spent in outdoor recreation, do not reveal the full picture. Consider an endangered species such as the whooping crane. A very small percentage of people will ever actually see such a rare bird. Yet, many more people may be willing to pay at least a small amount to help preserve the species. In this way, both users and nonusers of a resource may gain pleasure from its existence.

It is hard to place absolute dollar figures on the value of wildlife resources. Market data on many of the benefits due to wildlife are not available. Instead, estimating the consumptive and nonconsumptive value of wildlife resources requires the use of surveys of individual participation in hunting, fishing, and wildlife viewing. Since these surveys can be expensive to conduct, the value of many lesser-known species has not been studied. Furthermore, for nonuse benefits (such as existence values), values can be hard for respondents to articulate, particularly for little-understood or obscure species (such as invertebrates, small fish, and insects).

Despite these measurement challenges, it is possible to discuss a variety of factors that affect the amount of pleasure people gain from a wildlife resource. Table 3.1.3 lists some hunting (consumptive), viewing (nonconsumptive), and nonuse (existence) values for a variety of wildlife species. One factor affecting these values is whether or not there is a consumptive use for the resource, as well as the rules regulating consumptive use (such as harvest limits). For example, the average deer hunter is willing to pay $623 a year for the opportunity to hunt under current conditions.

Nongame birds, like the whooping crane, may have passive use or existence values. Broad segments of the population may care about these species, although they may not be willing to pay large amounts to preserve them. Thus, when a large number of people have small (but nonzero) existence values for the whooping crane, the total value from society may be quite large.

The scarcity or abundance of a species is also an important determinant of value. Abundant species may have lower values per animal than rare species, but generally offer more frequent opportunities for interaction with people. For example, individual hunters have paid more than $10,000 to hunt trophy elk and as much as $70,000 for bighorn sheep (Lueck, 1995).

Table 3.1.1—Participation in outdoor recreation activities, people 16 years and older, 1994

Type of activity	Percent of population participating: North	South	West	Pacific	National	Average number of trips by participants
Bird watching	28	26	28	23	27	27
Wildlife viewing	32	29	37	30	31	32
Hunting, big game	7	8	10	4	7	7
Hunting, migratory waterfowl	2	3	4	2	2	2
Studying nature near water	27	26	25	32	28	28

Source: National Survey of Recreation and the Environment (Cordell et al., 1997)

Table 3.1.2—Trends associated with wildlife-based recreation, 1991-1996

Variable	Units	1991	1996	Percent change
U.S. population (16 years or older)	Thousand people	189,964	201,472	6.3
Household median income	1999 constant dollars	33,686	36,850	2.3
Number of sportsmen	Thousand	39,979	39,694	0
Number of hunting or fishing days	Million	747	883	18.2
Nonconsumptive users	Thousand	76,111	62,868	-17.4

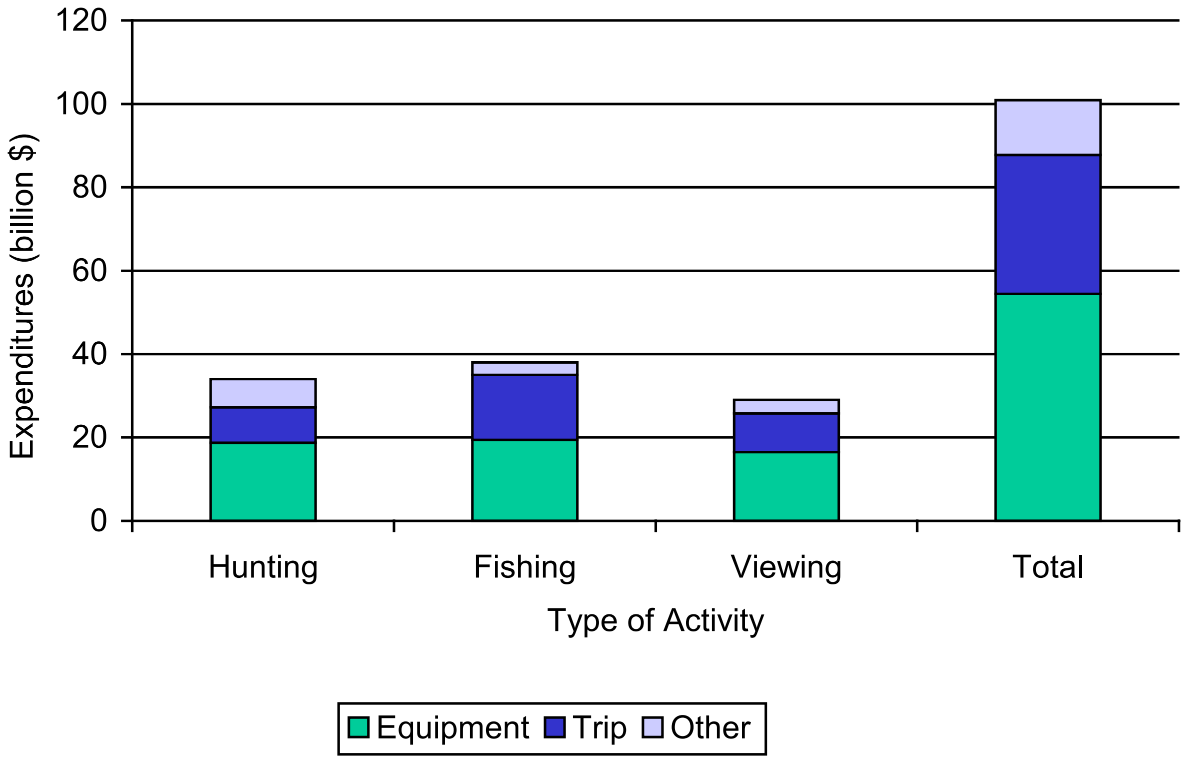
Source:1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (U.S. Dept. of the Interior, 1996)

Table 3.1.3— Selected estimates of the value of wildlife goods and services per individual

Good or Service	Source	Estimated willingness to pay (WTP)
		2000 constant dollars
		Annual WTP
Deer hunting [1]	Waddington et al., 1994	623
Bass fishing [1]	Waddington et al., 1994	550
Trout fishing 1	Waddington et al., 1994	475
Wildlife viewing [1]	Waddington et al., 1994	353
Elk hunting [1,4]	Buschena et al., 2001	292
Pheasant hunting [1,5]	Feather, Hellerstein and Hansen, 1999	215
Waterfowl hunting [1]	John et al., 1995	72
Grizzly bear [2]	Loomis and White, 1996 [3]	54
Whooping crane [2]	Bowker and Stoll, 1988	41
Red-cockaded woodpecker [2]	Loomis and White, 1996 [3]	15
	One-time (lump sum) WTP	
Bald eagle [2]	Loomis and White, 1996 [3]	256
Gray wolf [2]	Loomis and White, 1996 [3]	79
Northern spotted owl [2]	Hagen et al., 1992	63
Mexican spotted owl [2]	Loomis and Ekstrand, 1997	45

[1] Estimate is the yearly WTP, by participants, to hunt (or fish) for this species (under current conditions).
[2] Estimate is for preservation of the species.
[3] Values are reported in the source listed, but are derived from another study or studies.
[4] Estimate is for out-of-State hunters.
[5] Estimate is for hunters travelling less than 100 miles (95% of pheasant hunters).

Figure 3.1.2-Estimated expenditures by wildlife-oriented recreation participants



Similarly, species that are concentrated near large human populations may provide greater use values than species in remote locations, simply because more people have opportunities to view or hunt them. Abundance and scarcity can also lead to regional differences in the values that people place on a resource. Finally, a less tangible factor is what is sometimes called the *charisma* of the resource. People have expressed higher values for highly visible, emotive and well-known charismatic species, such as bald eagles, than for rarer but more obscure species, such as the red-cockaded woodpecker.

How does agriculture contribute to these popular wildlife-oriented activities? Agricultural lands are a major supplier of both wildlife habitat and access to wildlife-related goods and services, In addition, the value of open space (such as farmland) to wildlife-related recreation is a function of how many people can take advantage of it. Hence, it is instructive to examine the geographic extent of agriculture, and to examine where people live in relation to agricultural lands.

The proximity of agricultural land to the American public

Due to the vast quantities of land and water resources directly affected by the farm sector, and the geographic distribution of those resources, U.S. agriculture plays a major role in protecting and enhancing the Nation's wildlife. In 1997, agricultural lands comprised about 62 percent of all land in the contiguous 48 states (figure 3.1.3). This includes 349 million acres of cropland used for crops, 578 million acres of grassland pasture and range, 67 million acres of cropland pasture, 140 million acres of forest land grazed, and 39 million acres of idle cropland, mostly idled by the Conservation Reserve Program (CRP) (see Chapter 1.1, Land Use).

The bulk of lands held in public forests and parks lies in the Western U.S. (figure 3.1.3)., and is not easily accessible to a large portion of the population. Among USDA farm resource regions, the Federal Government owns less than 9 percent of all lands in the Heartland, Northern Crescent, Prairie Gateway, Southern Seaboard, and the Mississippi Portal. Similarly, within the contiguous 48 States, the farm sector owns most of the 92 million acres of rural non-Federal wetlands. Cropland, pasture, and range uses also account for 82 percent of the 83 million acres of converted wetlands (Heimlich et al., 1998).

Much of the U.S. population is concentrated in larger metropolitan areas east of the Mississippi River and on the West Coast (figure 3.1.4), the majority of the U.S. population lives in or near agricultural lands (compare figures 3.1.3 and 3.1.4). Over 70 percent of the U.S. population lives in counties that are at least 10 percent farmland (figure 3.1.5).

The wide extent of agricultural lands, and the proximity of much of the U.S. population to these lands, suggests that agricultural practices and their effects on fish- and wildlife-based recreational opportunities are likely to be of concern to many people. Therefore, how agricultural practices affect wildlife, and how agricultural land use decisions modify these impacts, is likely to have measurable impacts on social well-being.

Wildlife impacts of agricultural land use decisions

The variety and quantity of wildlife populations, as well as other natural goods and services, are ultimately determined by the uses of the land. Agricultural land use can benefit some species, harm others, and sometimes do both (see box, "Unexpected ecosystem effects can complicate agricultural impacts on biological resources"). Potentially harmful effects of farming include plowing up habitat, farming riparian buffers, diversion of water for irrigation, and diffusion of agricultural chemicals. In addition, specialization in agriculture reduces landscape diversity, creating more of a monoculture. This reduces the presence of ecological niches, which can limit wildlife populations (see box, "Some Impacts of Agriculture on Wildlife Habitat and Ecological Diversity"). These effects need not be permanent, and different forms of agricultural land use can have widely varying impacts on wildlife populations (table 3.1.4).

Unexpected ecosystem effects can complicate agricultural impacts on biological resources

In some cases agriculture's beneficial impacts on a species can impair other ecological functions. For example, a recent boom in light geese, a population group that includes snow geese and other similar birds, is attributed to the abundance of cereal grain crops in and near Kansas, which has shortened the birds' migration and improved their diets. The establishment of sanctuaries along their migration paths, and a decline in light geese harvest rates, has also increased light geese numbers to a current population of over 5 million. The geese summer in the far north, and their oversized population is accused of stripping clean tundra flora, which does not quickly or easily regrow. Thus, abundant habitat created by agriculture in one part of their range has created a situation where there are too many geese (in terms of available plant resources) in another part of their range (U.S. FWS 1998).

The relationship between wildlife and agricultural land use decisions can be described in four steps (figure 3.1.6). In order to maximize the present value of net farm income (over some relevant time horizon), farmers allocate land and water resources to commodity production, undisturbed habitat, and development. The land use decision for a given parcel implies a different set of land use activities, which in turn, imply a different set of wildlife impacts (second and third rows). Wildlife impacts from agriculture are the net effect of each land use, and are valued by society as costs or benefits associated with agricultural production.

Figure 3.1.3-Dominant cover and land use types, 1992

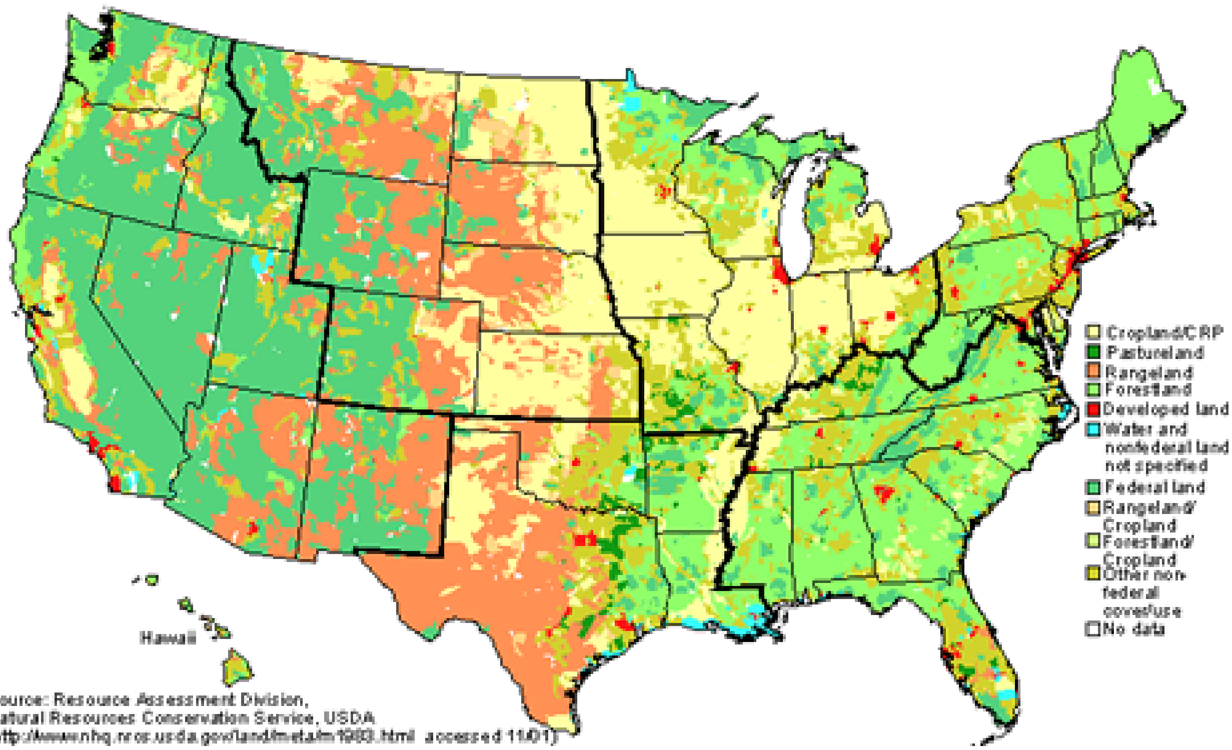


Figure 3.1.4-U.S. population density, 1990

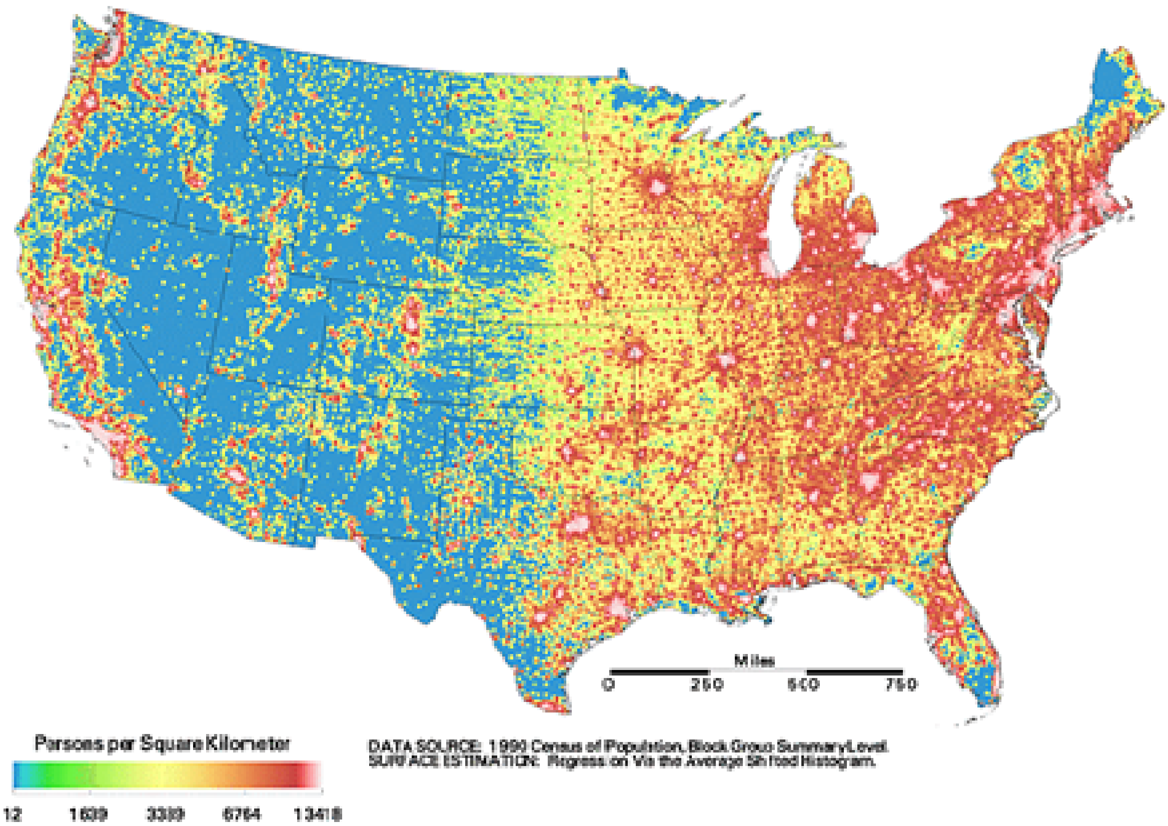
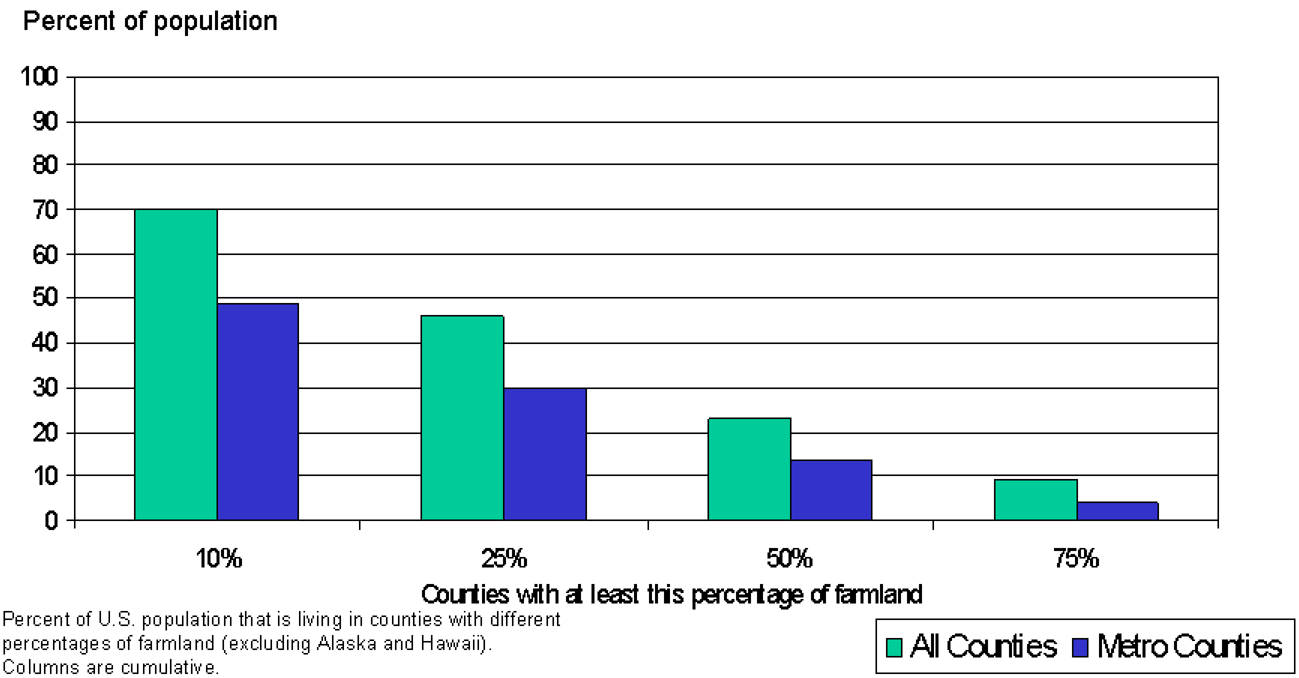


Figure 3.1.5-Population and farmland, 1997



Percent of U.S. population that is living in counties with different percentages of farmland (excluding Alaska and Hawaii).
Columns are cumulative.
Indicated percentage includes all counties that are that percentage or more farmland.
Metro counties as defined by Butler, 1994.

Some Impacts of Agriculture on Wildlife Habitat and Ecological Diversity

Habitat loss associated with agricultural practices on over 400 million acres of cropland is the primary factor depressing wildlife populations in North America. (Wildlife Management Institute, 1995) Modern farming methods brought about dramatic reductions in many species, including cottontail rabbits and ring-necked pheasants (Risley et al., 1995).

Annual wetland loss fell from the 458,000-acre average of the mid-1950s through the mid-1970s, to a 290,000-acre average between the mid-1970s and mid-1980s (Dahl and Johnson, 1991; Frayer et al., 1983) and 32,600 acres between 1992 and 1997. Wetland losses often reduce biodiversity because many organisms depend on wetlands and riparian zones for feeding, breeding, and shelter (Notivki et al., 1996).

Agriculture is thought to affect the survival of 380 of the 663 species listed by the Federal Government as threatened or endangered in the contiguous 48 United States (AREI 1997).

Table 3.1.4—Impacts of approved CRP wildlife habitat enhancement practices for selected species[1]

	Species										
Practice	Ring-necked pheasant	Gray partridge	Bob-white quail	Sharp-tail grouse	Prairie chicken	Upland nesting waterfowl	Neo-tropical migrant birds	Deer	Eastern cotton tail	Grass land birds	Predators
Tame Grasses:											
Northern Great Plains	+	+	+	+	+	+	+	+	+	+	+
Southern Great Plains	-	-	-	-	-	-	-	-	-	-	+
Native Grasses:											
Northern Great Plains	+	+	-	+	+	+	+	+	+	+	+
Southern Great Plains	+	+	+	+	+	+	+	+	+	+	+
Trees	-	-	-	-	-	-	+	+	+	-	+
Wildlife Plantings	+	+	+	+	+	-	+	+	+	-	+
Field Windbreaks	+	+	+	+	-	-	+	+	+	-	+
Already in grass	+	+	+	+	+	+	+	+	+	+	+
Shelterbelts	+	+	+	+	-	-	+	+	+	-	+
Small fields interspersed with cropland	+	+	+	-	-	-	+	+	+	-	+
Large (> 80 acres) contiguous units of grassland	+	-	-	+	+	+	-	+	-	+	-
Grassland adjacent to:											
Wetlands	+	+	+	+	+	+	+	+	+	+	+
Woodlands	+	+	+	-	-	-	+	+	+	-	+
Shelterbelts/ windrows	+	+	-	+	-	-	+	+	+	-	+
Cropland	+	+	+	+	+	-	+	+	+	-	+

[1] "+" implies a positive effect and "-" implies a negative effect.
Source: Allen (1993).

In general, the value of wildlife benefits will be highest when land is allocated to undisturbed habitat, lowest when land is developed, and will take some intermediate value when land is in agricultural production. These relationships highlight three points relevant to the design and implementation of policies to make farmland uses more compatible with wildlife.

First, there are several land use decisions that can be viewed as protecting wildlife resources associated with agricultural lands. Conditions for wildlife will be sustained or improved when existing habitat is maintained, existing cropland or pasture is converted to habitat better suited to wildlife, or existing cropland or pasture is not developed. In addition, the use of environmentally sensitive agricultural management practices (such as buffer strips around critical areas) can reduce agriculture's impacts on wildlife habitat.

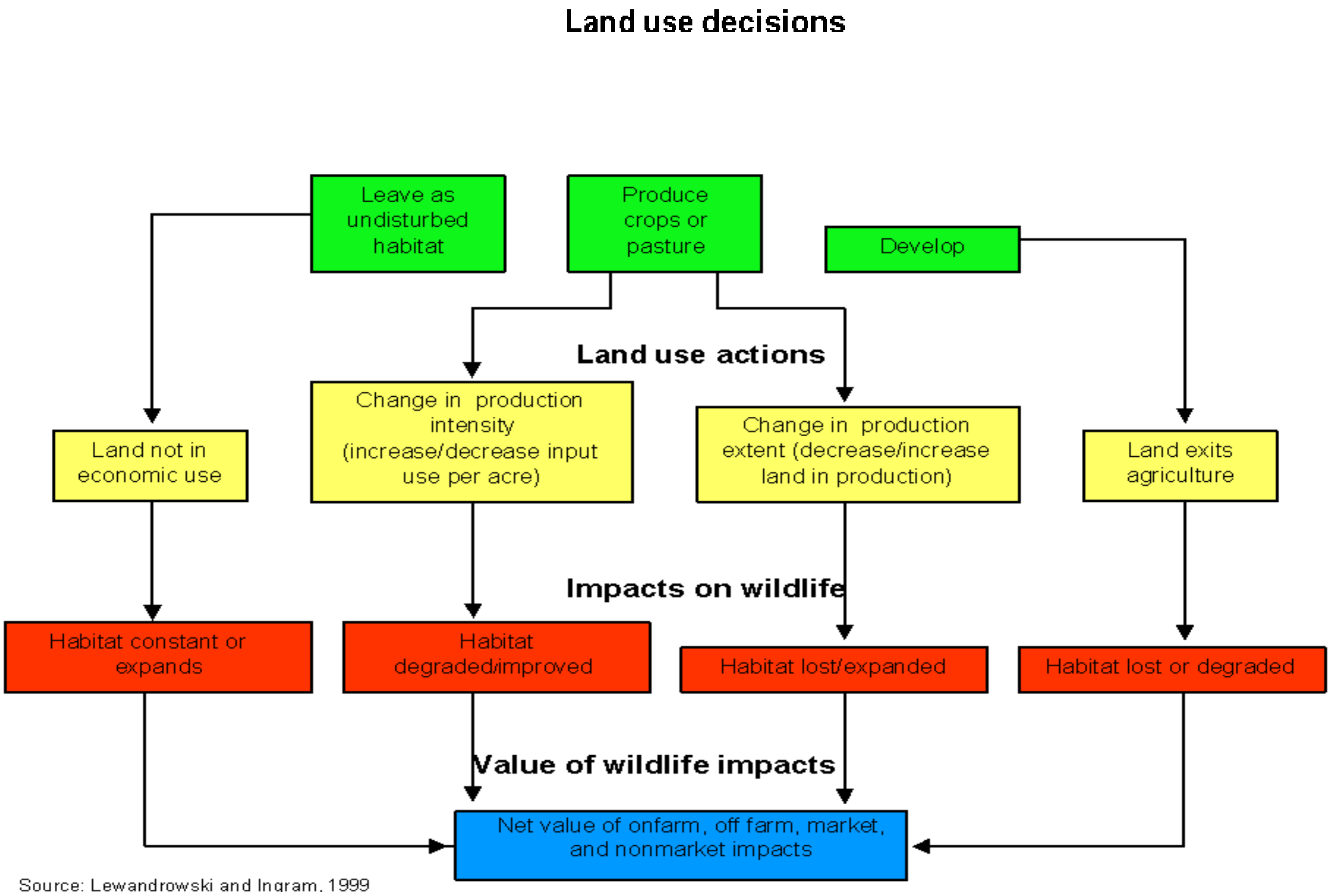
Recognizing that cropland and pasture can provide at least some amount of wildlife benefits is important because the cost of letting land remain in production can be significantly less than the cost of shifting it to undisturbed habitat. For example, in Lancaster County, Pennsylvania, urban growth has driven farmland prices as high as $12,000 an acre, which represents the opportunity cost of permanently restoring cropland to undisturbed wildlife habitat (Wiebe et al.,1996). The Lancaster Farmland Trust, however, has purchased development rights to some 16,900 acres for about $2,000 per acre. In designing a program to protect wildlife resources in Lancaster County, a key economic question is whether 6 acres of cropland produce more or less wildlife goods and services than 1 acre of undisturbed habitat. More generally, while undisturbed habitat may be the land use associated with the greatest wildlife benefits, cropland or pasture may yield the greatest wildlife benefits per conservation dollar.

Conversely, cropland retirement may sometimes yield substantial wildlife benefits. For example, converting cropland to CRP land, with attendant increases in wildlife quantity, accounts for nearly half of pheasant hunting benefits, and 5 percent of wildlife viewing benefits estimated across the Nation for 1992 (Feather, Hellerstein and Hansen, 1999). If the CRP had been distributed based on a broad array of environmental concerns (rather than the original targeting based on soil erosion), and had accounted for the proximity of CRP lands to population centers, wildlife viewing benefits would likely have been increased by approximately $287 million per year (over the $347 milllion in benefits attributed to the CRP as originally targeted).

A second point highlighted in figure 3.1.6 is that there are conditions under which allocating land use to natural habitat is economically rational. Land may be retained as natural habitat because it is too costly to convert to cropland or other forms of agricultural production, or because the highest valued land use is as habitat. For example, almost 28 percent of Texas farmlands (about 36.3 million acres) are leased for recreational hunting (Thigpen et al., 1992). In a survey of these farms, nearly 70 percent of the respondents indicated that they offered lease hunting to increase farm income, with much of this hunting occurring on land specifically set aside from agricultural uses. Where undisturbed habitat is too costly to convert (to farmland), or is the most profitable land use, there will generally not be a need for government actions to protect it.

Alternatively, a landowner may have allocated land as habitat because of an economic incentive, such as payments for CRP or Wetland Reserve Program (WRP), or penalties for cropping lands affected by the Swampbuster or Sodbuster provisions of the Farm Act (see chapters 6.2 and 6.3). In these cases the removal of the incentive, such as the expiration of a CRP contract or a phase-out of market transition payments used to leverage compliance, could eliminate the incentive farmers have to keep lands as habitat. Phasing out

Figure 3.1.6–Agricultural land use decisions and wildlife



Source: Lewandrowski and Ingram, 1999

Swampbuster could result in conversion of 1.5 to 3.3 million acres of privately owned wetlands to agricultural production (Claassen et al, 2000). Finally, figure 3.1.6 shows that agriculture can affect wildlife through two general processes—the increased use of agricultural chemicals, manpower, and other variable inputs (*intensification*); or by bringing nonagricultural lands into production (*extensification*).

For a given tract of land, these processes are associated with different sets of wildlife impacts. For example, as of September 1995, some 663 plant and animal species in the lower 48 States were listed by the Federal Government as threatened or endangered with extinction (Vesterby, Chapter 1.1, Land Use, 1996). Of these, 272 were listed, at least in part, due to agricultural development (extensification) and 115 due to the use of fertilizers and/or pesticides (intensification).

Since land and variable inputs are often substitutes in farm production, the relationship between intensification and extensification can complicate the design of policies to protect wildlife on agricultural lands. For example, where producers respond favorably to incentives to allocate more land and water to wildlife, they may also use more chemicals, field operations, and other secondary inputs on land remaining in production. In such cases, efforts to protect species by retiring less profitable farmland (farmland at the *extensive margin)* may come at a cost of negatively impacting other species that live on the now more heavily manipulated farmland (farmland within the *intensive margin*).

Agriculture and Genetic Resources

Genetic resources are the genes found in all living things. While all biological resources contain genes, discussions about genetic resources tend to focus on agricultural plants and livestock breeds and their wild relatives. All agricultural commodities descend from various wild and improved genetic resources. With the advent of biotechnology, genetic resources for improvement of agricultural crops and livestock may even include genetic material from unrelated, nonagricultural species. As a critical input, these genetic resources enhance domestic and world food security through increased productivity and protection against yield variability due to diseases, pests, and environmental stress.

Before the development of modern varieties, farmers developed their own varieties of crops or livestock (landraces). Today, the use of modern breeding techniques has led to genetic improvements that have increased yields (and lowered costs) for producers. However, agricultural producers face pests and diseases that constantly evolve, and breeders continually search for resistance traits to keep high-yielding varieties less vulnerable. Therefore, genetic resources (including wild relatives and landraces) are always needed to maintain and improve current yields. The collection, preservation, and sustained use of genetic resources have become critical for continued agricultural productivity.

Genetic resources can be maintained in their natural environments (*in situ* preservation), or can be stored in genebanks (*ex situ* preservation). Most of the world's genetic resources are found in their natural environment. At the same time, the resources used by breeders are generally those that have already been collected and preserved outside their native habitats. Each conservation approach has different costs and benefits, and the two approaches complement each other. Finding the proper mix of preservation strategies is a complex task that is complicated by limited funds and the loss of natural habitat, particularly in developing countries where many resources are found.

Two related issues can also affect the pool of genetic resources used in agriculture. First, some scientists believe that the genetic base has narrowed, and crops have become more genetically uniform. Genetic uniformity can increase the risks of pests and diseases spreading throughout a crop or livestock variety, as occurred in the 19th-century Irish potato famine and the U.S. southern corn leaf blight of 1970. Second, access to genetic resources found in other countries has been critical to maintaining the pool of genetic resources. Almost every plant species of major economic importance to the United States has been improved with germplasm from elsewhere (GAO, 1997). Tensions over the ownership of (and payment for) genetic resources have complicated the ability of the United States to collect new germplasm from international sources.

In addition to contributing to the production of traditional crops, genetic resources are increasingly used in a variety of other industries, contributing to the development of biologically based agrochemicals, novel food and cosmetics, new lubricants, and other industrial uses.

Biologically based agrochemicals are increasingly in demand, as society seeks to expand production through pest control while minimizing environmental damages. The pesticide/fungicide *neem* is one example of a natural compound being used as an agricultural chemical. Natural compounds can have other industrial uses, for example, as lubricants and for biological pollution control agents. The food industry uses natural flavorings and preservatives. The cosmetics industry also uses natural compounds. *Jojoba* is one example of a previously little-known genetic resource that has been economically important for cosmetic manufacturers.

Genetic resources also contribute heavily to the development of pharmaceuticals. Natural products (that is, products derived from naturally occurring living things) have long been a source of medicinal substances. Twenty-five percent of the prescription drugs sold in the United States contain active ingredients derived from plants (Reid, 1995). Even more drugs originally came from plant or animal products, or use natural products in some part of the formula. Worldwide, the World Health Organization estimates that 80 percent of the world's population relies on plant-based medications (*Lancet*, 1994).

Genetic resources can also affect the indirect inputs to agriculture. For example, pollinators (such as bees, butterflies, hummingbirds, and moths) are critical for crops requiring direct pollination. While different pollinators are best suited for different crops, the United States has come to rely heavily on honeybees. The cultivation of honeybees, along with pesticide use and habitat loss, has reduced the level and diversity of pollinators used by U.S. agriculture. The first consequence of this loss in diversity is that a significant portion of the pollinator population, lacking diversity, has become increasingly vulnerable to pests. This is one reason honeybee populations have fallen significantly in recent years due, in part, to parasitic mites. Secondly, other pollinator populations have declined too much to compensate for the honeybee loss. As a result, inadequate pollination has reduced yields for certain crops (Allen-Wardell et al., 1998).

Comparing Wildife and Genetic Resources

Wildlife habitat and genetic diversity share a common feature: the benefits they provide to society are often not bound up in marketable commodities. Hence, it is often difficult for rural landholders to profit from the protection and preservation of these biological resources. This does not mean that wildlife habitat and genetic diversity have no value. In fact, many people appreciate the reality that wildlife live on agricultural lands, and that growth in agricultural productivity is greatly enhanced by genetic diversity. But society has no means to register the values they hold for wildlife and genetic resources in a way that gives farmers (and other rural landholders) incentives to consider these benefits when making decisions on how to use their lands. Thus, wildlife habitat and genetic diversity tend to be underprovided—the Nation would be better off if the protection and preservation of these resources were given greater consideration by rural landholders.

The existence of this "market failure" suggests that government can play a role. Government policies, such as the maintenance of gene banks, can directly increase the provision of biological resources. In addition, government programs that work with the private sector, such as the Environmental Quality Incentives Program (EQIP), which provides subsidies for environmentally sensitive production practices, and the Conservation Reserve Program (CRP), which restores environmentally sensitive land, can also be effective in increasing the supply of wildlife habitat.

Though wildlife habitat and genetic diversity have common goals for onsite (*in situ*) preservation, there are few opportunities for offsite (*ex situ*) wildlife preservation. Although there are some programs that protect wildlife off site, such as captive breeding of endangered species in zoos, the primary means of protecting wildlife populations is to protect their habitats. In contrast, U.S. genetic diversity is protected primarily through maintaining collections of seeds, rather then through protection of plant habitat. The major reason for the U.S. emphasis on *ex situ* preservation is that few remaining unexploited crops are native to the United States, hence there are few domestic locales where "wild" varieties of important crops can be protected in place.

The following two chapters consider government programs that influence the provision of biological resources. Chapter 3.2 considers wildlife issues in greater detail, with a focus on policy tools for protecting wildlife habitat associated with agriculture. In Chapter 3.3, the use of genetic resources in agriculture is examined in detail. Critical links between agriculture and genetic diversity are described, along with economic issues underlying the conservation of genetic resources, and policies intended to promote genetic resource preservation.

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References

Aiken, Richard 1999. “1980-1995 Participation in Fishing, Hunting, and Wildlife Watching: National and Regional Demographic Trends.” Report 96-5, U.S. Fish and Wildlife Service. (at http://www.fws.gov/r9fedaid/ accessed 11/01).

Allen, Arthur W., 1993. *Wildlife Habitat Criteria in Relation to Future Use of CRP Lands*, in Proceedings of the Great Plains Agricultural Council Annual Meeting. 8.

Allen-Wardell, G., P. Bernhardt, R. Bitner, A. Burquez, S. Buchmann, J. Cane, P. A. Cox, V. Dalton, P. Feinsinger, M. Ingram, D. Inouye, C. E. Jones, K. Kennedy, P. Kevan, H, Koopowitz, R. Medellin, S. Medellin-Morales, G. P. Nabhan, B. Pavlik, V. Tepedino, P. Torchio. S. Walker (1998). "The Potential Consequences of Pollinator Declines on the Conservation of Biodiversity and Stability of Food Crop Yields," *Conservation Biology*. Vol. 12, No. 1. pp. 8-17.

Bowker, J. and J. Stoll. 1988. “Use of Dichotomous Choice Nonmarket Methods to Value the Whooping Crane Resource.” *American Journal of Agricultural Economics* 70(2):372-381.

Buschena, D., T. Anderson and J. Leonard. 2001.“Valuing Non-Marketed Goods: The Case of Elk Permit Lotteries.” *Journal of Environmental Economics and Management* 41(1):33-43.

Butler, Margaret, and Calvin Beale. 1994. *Rural-Urban Continuum Codes for Metro and Nonmetro Counties*. Staff report No. 9425, U.S. Dept. Agr., Econ. Res. Serv., Sept.

Claassen, R., L. Hansen, M. Peters, V. Breneman, M. Weinberg, A. Cattaneo, P. Feather, D. Gadsby, D. Hellerstein, J. Hopkins, P. Johnston, M. Morehart, and M. Smith. 2001. *Agri-Environmental Policy at the Crossroads: Guideposts on a Changing Landscape*. Agricultural Economic Report No. 794, U.S. Dept. Agr., Econ. Res. Serv., Jan.

Cordell, Ken. 1998. Outdoor Recreation in American Life: A National Assessment of Demand and Supply Trends. Sagamore Publishing, Champaign IL.

Cordell, K., J. Teasley, G. Super, J. Bergstrom and B. McDonald. 1997. *Outdoor Recreation in the United States: Results from the National Survey on Recreation and the Environment*. USDA Forest Service and the University of Georgia (at http://www.fs.fed.us/research/rvur/recreation/publications/outdoor_recreation/title.htm accessed 11/01).

Dahl, T. E. 1990. *Wetlands Losses in the United States, 1780's to 1980's.* Washington, D.C: Department of the Interior, U.S. Fish and Wildlife Service.

Feather, P., D. Hellerstein, and L. Hansen. 1999. *Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: The Case of the CRP*. Agricultural Economic Report No. 778. U.S. Dept. Agr., Econ. Res. Serv., Apr.

Frayer, W.E., T.J. Monahan, D.C. Bowden, and F.A. Graybill. 1983. *Status and Trends of Wetlands in the Conterminous United States, 1950's to 1970's.* Fort Collins, CO: Department of Forest and Wood Sciences, Colorado State University.

Hagen, D., J. Vincent and P. Welle. 1992. “Benefits of Preserving Old-Growth Forests and the Spotted Owl.” *Contemporary Policy Issues* 10(April):13-26.

Heimlich, Ralph, Keith Wiebe, Roger Claassen, Dwight Gadsby, and Robert House. 1998. *Wetlands and Agriculture: Private Interests and Public Benefits.* Agricultural Economic Report No. 765. U.S. Dept. Agr., Econ. Res. Serv., Sept.

John, K., R. Walsh and R. Johnson. 1995. “Valuation of Wetland as Waterfowl Habitat: Iterated Referendum Approach.” Presented at the August, 1995 AAEA meeting, Indianapolis.

Lancet, The. 1994. "Pharmaceuticals from Plants: Great Potential, Few Funds" (Editorial). 343(8912): 1513-1515.

Lewandrowski, J., and K. Ingram. 1999. "Policy Considerations for Increasing Compatibilities between Agriculture and Wildlife." *Natural Resources Journal.* 38(2):229-69

Loomis, J. and E. Ekstrand. 1997. "Economic Benefits of Critical Habitat for the Mexican Spotted Owl: A Scope Test Using a Multiple-Bounded Contingent Valuation Survey." *Journal of Agricultural and Resource Economics* 22(2):356-366.

Loomis, J. and D. White. 1996. "Economic Benefits of Rare and Endangered Species: Summary and Meta-Analysis." *Ecological Economics* 18(3):197-206.

Lueck, D. 1995. "Property Rights and the Economic Logic of Wildlife Institutions." *Natural Resources Journal* 35(3):625-670.

Novitski, R.P., R.D. Smith, and J.D. Fretwell. 1996. "Wetland Functions, Values, and Assessment." in J.D. Fretwell, J.S. Williams, and P.J. Redman (eds.), *National Summary on Wetland Resources*. USGS Water Supply Paper 2425, pp. 79-86. Washington, D.C: U.S. Department of the Interior, U.S. Geological Survey.

Olmstead, A., and D. Wooten. 1987. "Bee Pollination and Productivity Growth: The Case of Alfalfa." *American Journal of Agricultural Economics*, 69(1):56-83.

Reid, W. V. (1995). "Biodiversity and Health, Prescription for Progress." *Environment*, 7(6): 12-15, 35-39.

Risley, David L., Alfred H. Berner, and David P. Scott. 1995. in *How Much is Enough? A Regional Wildlife Habitat Needs Assessment for the 1995 Farm Bill*, compiled and edited by Donald F. McKenzie and Terry Z. Riley of the Wildlife Management Institute, Washington, DC, Feb.

Thigpen, Jack, Charles Ramsey, and James Stribling. 1997. "Hunter expenditure to rural communities and landowners: Gillespie County case study." Texas Agricultural Extension Service, College Station, TX (at http://agpublications.tamu.edu/pubs/wf/a009.pdf accessed 11/01).

U.S. Department of the Interior. 1996. "1996 National Survey of Fishing, Hunting, and Wildlife Associated Recreation." U.S. Dept. of the Interior, Fish and Wildlife Service.

U.S. Fish and Wildlife Service. 1998. "Snow Goose FAQs," Jan. (at http://migratorybirds.fws.gov/issues/snowgse/faqs.html accessed 11/01).

U. S. General Accounting Office. 1997. *U. S. Department of Agriculture: Information on the Condition of the National Plant Germplasm System.* Report to Congressional Committees. Washington, DC: U. S. General Accounting Office.

Vesterby, M. 1997. Land Use, Ch. 1.1, *Agricultural Resources and Environmental Indicators: 1996-97*. Agricultural Handbook No. 712. U.S. Dept. Agr., Econ. Res. Serv., July.

Waddington, D., K. Boyle and J. Cooper. 1994. *1991 Net Economics Values for Bass and Trout Fishing, Deer Hunting, and Wildlife Watching*. Division of Federal Aid, U.S. Fish and Wildlife Service.

Wiebe, K., A. Tegene, and B. Kuhn. 1996. *Partial Interests in Land: Policy Tools for Resource Use and Conservation*. Agricultural Economic Report No. 774. U.S. Dept. Agr., Econ. Res. Serv., Nov.

Wildlife Management Institute. 1995. *How Much is Enough?: A Regional Wildlife Habitat Needs Assessment for the 1995 Farm Bill*, compiled and edited by Donald F. McKenzie and Terry Z. Riley of the Wildlife Management Institute, Washington, DC, Feb.