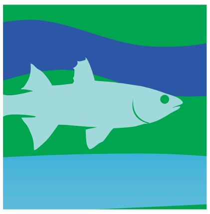
COUNTRY REPORTS



THE STATE OF **THE UNITED STATES OF AMERICA'S** BIODIVERSITY FOR FOOD AND AGRICULTURE

U.S. Country Report on Biodiversity for Food and Agriculture 2015

Contents

List of Acronyms

ACEP: Agricultural Conservation Easement Program
ACWA: Association of the Clean Water Administrators
AFRI: Agriculture and Food Research Initiative
ARMS: Agricultural Resources Management Survey
ARS: Agricultural Research Service
BBS: Breeding Bird Survey
BLM: Bureau of Land Management
Bt: *Bacillus thuringiensis*
CAFO: Confined Animal Feeding Operations
CCC: Commodity Credit Corporation
CCD: Colony Collapse Disorder
CEAP: The Conservation Effects Assessment Project
CGRFA: The Commission on Genetic Resources for Food and Agriculture (of the FAO)
CPC: Center for Plant Conservation
CSP: Conservation Stewardship Program
CTA: Conservation Technical Assistance Program
CWA: Clean Water Act
DOI: Department of the Interior
EISA: Energy Independence and Security Act
EPA: Environmental Protection Agency
ESA: Endangered Species Act
EQIP: Environmental Quality Incentives Program
ERS: Economic Research Service
FAO: Food and Agriculture Organization of the United Nations
FMP: Fishery Management Plans
FS: Forest Service
FSA: Farm Service Agency
FWS: Fish and Wildlife Service
GE: Genetically Engineered
GHG: Greenhouse Gas
GR: Glyphosate Resistant
GRIN: Germplasm Resources Information Network
GT: Glyphosate Tolerant
HELC: Highly Erodible Land Conservation
HFRP: Healthy Forests Reserve Program
HT: Herbicide Tolerant
MOA: Modes of Action
MTBE: Methyl Tertiary Butyl Ether
NASS: National Agricultural Statistics Service
NGRP: National Genetic Resources Program
NIFA: National Institute of Food and Agriculture

NMFS: National Marine Fisheries Service
NOAA: National Oceanic and Atmospheric Administration
NPDRS: National Plant Disease Recovery System
NPCS: National Plant Germplasm System
NRCS: Natural Resources Conservation Service
NRI: National Resource Inventory
RFG: Reformulated Gasoline
RFS: Renewable Fuel Standard
RMA: Risk Management Agency
RMP: Resistance Management Practices
RNA: Research Natural Area
SARE: Sustainable Agriculture Research and Education
TMDL: Total Maximum Daily Load
TNC: The Nature Conservancy
USGS: U.S. Geological Service
WC: Wetland Conservation

U.S. Country Report
Biodiversity for Food and Agriculture 2015

1. Introduction

A complex web of biodiversity helps support food and agricultural production systems in the United States and around the globe. Biodiversity—from the smallest pollinator to the towering redwoods—contributes in known and unknown ways to improving the resilience and quality of food and agricultural production. The Commission on Genetic Resources for Food and Agriculture (CGRFA) of the Food and Agriculture Organization (FAO) of the United Nations describes this broad “associated” biodiversity as “the variety and variability of animals, plants and micro-organisms at the genetic, species and ecosystem levels that sustain the ecosystem structures, functions and processes in and around production systems, and that provide food and non-food agriculture products” (FAO-CGRFA 2013). This associated biodiversity is the topic of this report.

Evidence on biodiversity health and its impact on food and agriculture in the United States comes from limited data on a number of key indicators. The U.S. Country Report on Biodiversity for Food and Agriculture synthesizes information on these indicators to illustrate the dynamics between biodiversity and agriculture. This report is the U.S. contribution to the CGRFA’s report “State of the World’s Biodiversity for Food and Agriculture.” As per the CGRFA’s outline, this country report begins with an overview of the U.S. agricultural sector. It then examines major drivers of biodiversity change; trends in key biodiversity indicators; the use of biodiversity for food and agriculture; the role of policy in influencing biodiversity health; and data gaps and research needs. This report complements three other national reports on biodiversity and genetic resources: the *State of Forest Genetic Resources (2012)*, the *State of Plant Genetic Resources for Food and Agriculture (2011),* and the *State of Animal Genetic Resources (2014)*.

Source material for the U.S. Country Report on Biodiversity for Food and Agriculture is from data previously collected and analyzed by the U.S. Government or from research published in peer reviewed journals. A team of researchers at the U.S. Department of Agriculture (USDA) compiled the material and produced the first draft of the report. Input was solicited from researchers across the federal government. A full list of contributors to the report is in Appendix 1.

2. Overview of the United States and its Agricultural Sector

Geography, topography and weather are fundamental to the composition of and dynamics between biodiversity and agricultural production. In addition to these fundamentals, current land use patterns, crops grown, agricultural practices, and farm and farmer characteristics influence the direction of biodiversity change and its impacts on food and agricultural.

2.1 Geography

The United States of America is the fourth largest country in the world, with an area of 3.796 million square miles (9.857 million square kilometers). The forty-eight contiguous states, which are responsible for well over 99 percent of the total value of U.S. agricultural production, have a land area of 3.120 million square miles, or about 82 percent of the total area.

The terrain of the 48 contiguous states features a large central plain drained by the Mississippi River system, with the high Rocky Mountains and Sierra Nevada in the western region and the lower Appalachian Mountain range in the eastern region (Figure 2-1).

Figure 2-1. Major ecoclimatic zones for the United States

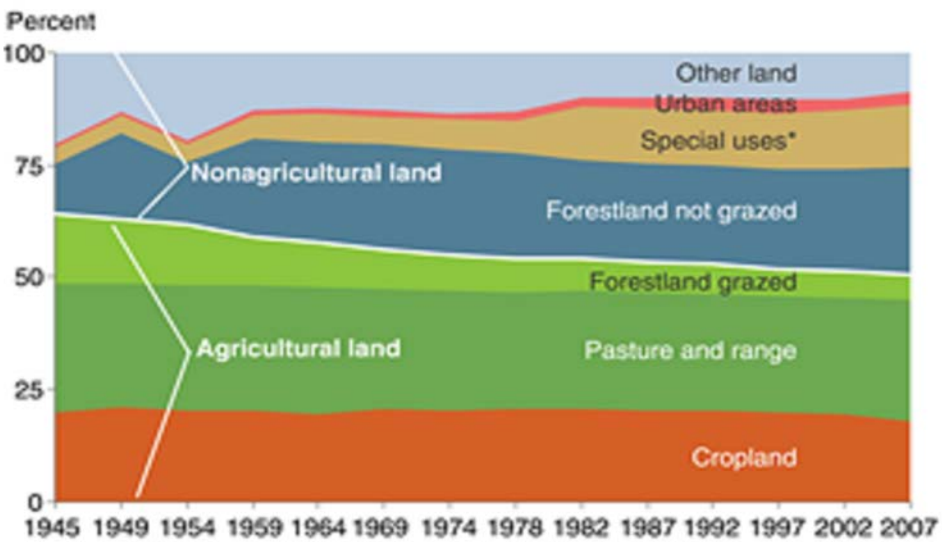
Source: USDA Forest Service (2013), based on Smith et al. (2009)

The northern temperate tier accounts for approximately two-thirds of the area of the 48 contiguous states. The additional one-third of the area is subtropical, with the exception of a very small tropical area in the extreme southeast. From east to west, humid regions are succeeded by semi-arid and finally arid regions, except for the western fringe of the contiguous states, particularly in the Pacific Northwest, which receives higher rainfall. Deserts are located in parts of the southwestern states of Arizona, California, Nevada, New Mexico, Texas and Utah.

2.2 Land-use and cropping patterns

The proportion of the land base in agricultural use in the United States declined from 63 percent in 1949 to 51 percent in 2007. Declines in cropland and pasture/range were gradual, while grazed forestland decreased more rapidly (Figure 2-2). Most land tends to remain in the same land category from year to year. From 2002 to 2007, between 96 and 99 percent of privately owned crop, pasture/range, and forest land remained in its pre-existing use. From 1982 to 2007, 78, 86, and 92 percent of cropland, pasture/range, and forest land, respectively, remained in those uses (Nickerson et al. 2011).

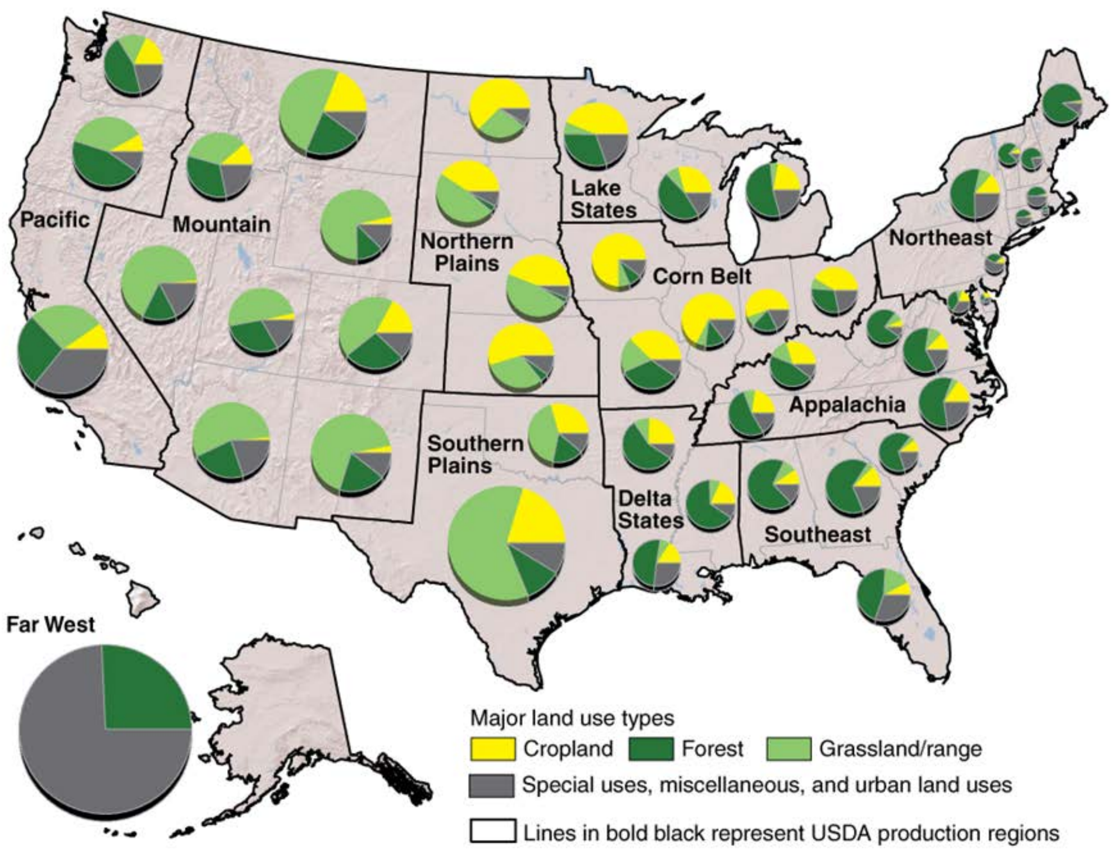
Figure 2-2. Changes in Major Land Uses in the United States over Time
(Other land use categories are special uses (primarily parks and wildlife areas), miscellaneous uses (such as tundra or swamps), and urban land (Nickerson et al. 2011).)



*Special uses includes rural parks and wilderness areas, rural transportation, defense/industrial lands, and farmsteads.
Source: USDA, Economic Research Service using data from the Major Land Uses series.

In 2012 approximately 402.5 million acres (162.9 million hectares), about 18 percent of the total U.S. land area, were classified as cropland, according to the Census of Agriculture (USDA NASS 2014). The 2012 Census of Agriculture found a roughly equivalent amount of land (415.3 million acres) in permanent pasture and in rangeland on farms. The total amount of U.S. land classified as "grassland, pasture, and range" rises to about 27 percent of total U.S. land area if non-farm private grazing land and public, non-forested grazing land are included. Another major land use category is forest land, at about 30 percent of the total. If only the 48 contiguous states are included cropland rises to roughly 21 percent and grassland, pasture, and range to about 32 percent of total land area (Nickerson et al. 2011). Figure 2-3 shows major land use shares by state for 2007.

Figure 2-3. Major Land Use Shares by State, 2007



Notes: The size of the pie charts is proportional to the land area in each State. The miscellaneous, special use, and urban areas categories were too small to effectively illustrate separately.
Source: See sources for figure 1. State estimates are summarized in the USDA/Economic Research Service, *Major Land Uses* data series, 2011.

U.S. farmers grow a wide range of crops, including cereal, oilseed, forage, sugar, vegetable, fruit and nut, and landscape or ornamental species. In 2012, the value of production exceeded $500 million for more than 30 crops, including corn, soybeans, forage crops (alfalfa and all other), wheat, cotton, potatoes, rice, peanuts, sugarbeets, sorghum, tobacco, sugarcane, dry edible beans, sunflower, grapes, almonds, citrus, apples, strawberries, lettuce, walnuts, sweet corn, pistachios, tomatoes, onions, cherries, broccoli, carrots, peaches, bell peppers, cucumbers, and ornamentals. Acreage harvested, production, and value of production for major crops produced in the U.S., according to the 2012 Census of Agriculture, are provided in Table 2-1. The production figures for individual fruit and vegetable crops are not shown.

Table 2-1. The number of acres harvested, production, and value of production of crops grown in the U.S. in 2012

Crop	Acres (thousands)	Production	Production Units	Value of Production (million dollars)
Corn (grain)	87,413	10,333.4	Million bushels	67,250.1
Corn (silage)	7,197	113,153.1	Thousand tons	NA
Soybeans	76,105	2,926.8	Million bushels	38,745.1
Hay (all)	51,540	110,945.2	Thousand dry tons	18,557.7
Wheat	49,040	2,185.1	Million bushels	15,761.5
Cotton	9,384	16,534.3	Thousand bales	6,137.6
Potatoes	1,168	464,970.0	Thousand cwt	3,914.9
Rice	2,694	200,239.3	Thousand cwt	2,895.1
Peanuts	1,622	6,660.5	Million pounds	2,308.7
Sorghum (grain)	5,142	264.3	Million bushels	1,764.4
Tobacco	343	766.6	Million pounds	1,491.2
Dry beans	1,643	31,424.3	Thousand cwt	1,269.7
Barley	3,284	215.1	Million bushels	1,228.2
Sunflowers	1,877	2,728.8	Million pounds	727.8
Sugarbeets	1,249	35,417.5	Thousand tons	NA[1]
Sugarcane	855	30,269.7	Thousand tons	NA[2]
Fruits, nuts, & berries (all species)	6,065	No common unit of measure		25,869.7
Vegetables & melons (all species excluding potatoes)	3,234	Same as above		12,436.3

Source: USDA NASS 2014; NASS Quick_Stats (http://www.nass.usda.gov/Quick_Stats/); USDA NASS 2013
[1]Approximately $2 billion in 2011. [2]Approximately $1.4 billion in 2011.

The market value of livestock products in 2012 was over $182 billion, or about 46 percent of total agricultural production. Inventories as well as values of production for major livestock commodities or commodity groups are shown in Table 2-2. Data are also reported for numbers of animals sold. Numbers of animals sold, however, do not provide a direct link to the value of the commodity, where value is determined by pounds of meat, pounds of milk, dozens of eggs, and so on. Furthermore, in species with rapid reproduction cycles, such as hogs and particularly poultry, numbers of animals sold can be much greater than inventories. The value of beef production in 2012 was the single largest commodity by value, livestock or crop, at over $76 billion. Poultry products, milk, and pork all accounted for roughly between $20 and $40 billion in 2012. Aquaculture, horses and related species, sheep and goats, and other animals and animal products all comprised relatively smaller amounts, approximately $1-$1.5 billion in 2012.

Table 2-2. Inventories, sales, and value of production for livestock raised in the United States, 2012

Livestock/poultry type	Inventory (thousand)	Number sold (thousand)	Amount sold	Value of Production (million dollars)
Beef cattle-cows	28,956.6			
Other beef cattle	51,785.8			
Beef cattle on feed (included in "other beef cattle")	*14,386.2*			
Cattle and calf sales		69,759.8		
Beef production				76,309.2
Dairy cattle—cows	9,252.3			
Milk production			200,642 million lbs	35,277.3
Hogs and pigs	66,026.8	199,115.3		
Pork production				22,492.6
Sheep & lambs	5,364.8			
Goats, all	2,621.5			
Meat, wool, mohair and milk production				939.7
All hatched poultry		9,819,660.4		
Pullets for laying flock replacement	110,792.2	176,802.4		
Layers	350,716.0	204,941.7		
Egg sales			6,842 million dz	
Broilers	1,506,276.8	8,463,194.8		
Roosters	7,564.8	8,354.8		
Turkeys	100,792.2	286,030.3		
All other poultry	16,041.5	63,143.3		
Poultry and products				42,751.5[1]
Horse, ponies, mules, burros, and donkeys				1,390.7
Aquaculture				1,552.4
Other animals and animal products				1,228.3

Source: USDA NASS 2014

[1]Approximately 70% of this value is from broilers; most of the rest is accounted for by eggs and turkeys.

The production of different crop and livestock commodities is widely dispersed across different regions in the United States and every major crop is grown in more than one region. However production of certain commodities is more concentrated in some regions than others. For crop production, climatic and soil conditions are more likely to influence the distribution of crop production while for livestock production, market conditions may be relatively more important than environmental factors.

Corn and soybean production is particularly concentrated in the Corn Belt (Figure 2-3), wheat in the Northern Plains and northern part of Mountain region. Fruits and vegetables are concentrated along the coasts in the Pacific, Southeast, and Southern Plains regions, with some additional production in the Northeast. Barley production is greatest in the Northern Plains and northern part of Mountain region. The largest peanut producing region threads through is the Delta States, the Southeast and eastern Appalachia. Sugarcane production is concentrated in the states of Florida, Louisiana, and southernmost Texas. Over time, production regions can shift. For many years, corn and soybean production has been concentrated in the Corn Belt, as it is today. However over the past 25 years or more, there has been expansion of corn and soybean production into the eastern reaches of the Northern and Southern Plains.

Among non-food crops, cotton is produced across the entire southern tier of the U.S. Most of the production is upland cotton, although there is significant production of extra-long staple cotton in California. Flue-cured tobacco production is concentrated primarily in the Southeast region and eastern Appalachia and burley tobacco production in western Appalachia. Forage crop production is widely dispersed, although alfalfa production is greatest in the western half of the contiguous 48 states.

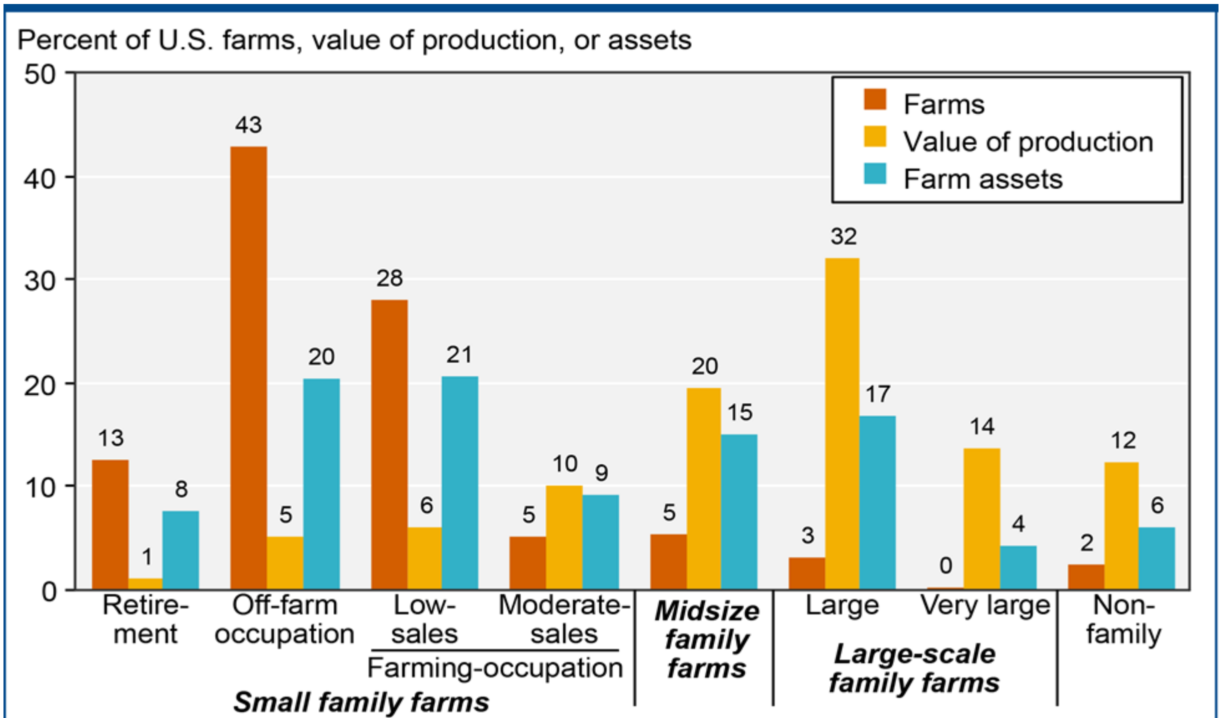
Cow-calf operations are located throughout the country, often on land unsuitable for crop production. Cattle feedlot production is also found in a number of regions, but the highest concentrations are in the Southern and Northern Plains regions. Dairy production in the United States is almost completely separate from beef production, and milk is produced in all 50 states. The largest values of dairy production are found in the Pacific region, with California the largest U.S. milk-producing state, and the Lake States region, where Wisconsin is the second largest U.S. milk-producing state. Hog production is particularly concentrated in the Corn Belt—particularly Iowa and southern Minnesota—and in the Southeast region and eastern Appalachia regions, primarily in North Carolina. Broiler production is concentrated in the Southeast and Appalachia regions and adjacent parts of the Delta States. Turkey and egg production are somewhat more scattered geographically.

2.3 Farm structure and organization

Based primarily on USDA's Economic Research Service website on farm structure (USDA ERS, 2015); Hoppe (2014); MacDonald et al. (2013); and MacDonald and Marion (2015)

The structure of farms in the United States is a topic of intense interest. The USDA Economic Research Service (ERS) classifies U.S. farms into small family farms, midsize family farms, large-scale family farms, and nonfamily farms, with further subdivisions into a total of eight classes. In 2013, 98 percent of U.S. farms were family farms. Small family farms accounted for 89 percent of U.S. farms, 58 percent of farm assets, but only 22 percent of agricultural production (Figure 2-4). Most large farms in the U.S. are still family owned and operated. Most nonfamily farms are not large farms operated by publicly held corporations. Only 17 percent of non-family farms are organized as corporations, and 94 percent of these report no more than 10 stockholders (Hoppe, 2014).

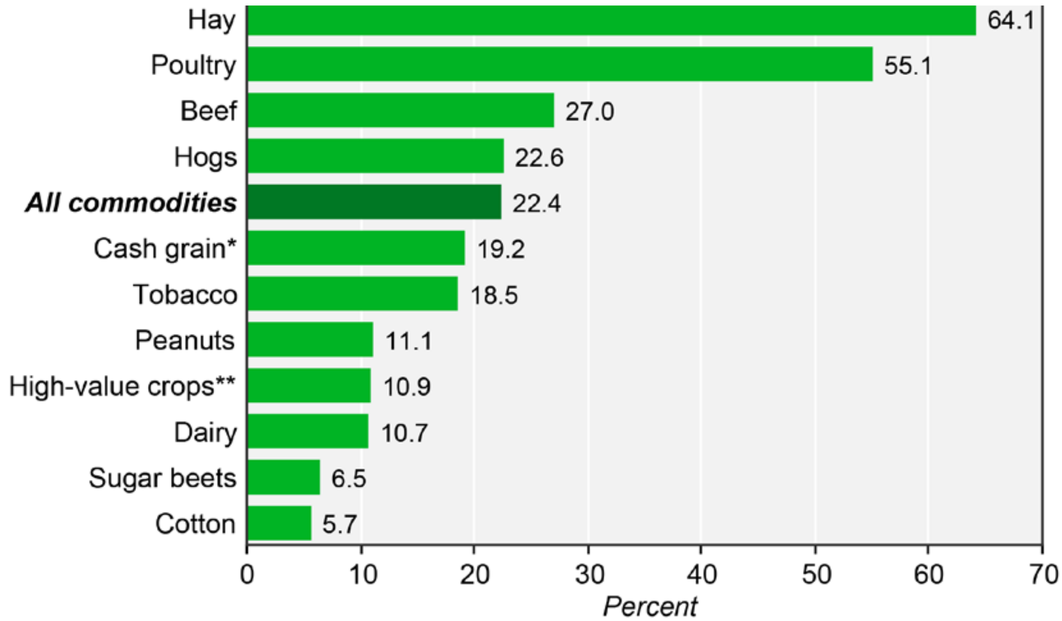
Figure 2-4. Distribution of farms, value of production, and farm assets, 2013



Note: Small family farms have gross cash farm income (GCFI) < $350,000. Midsize family farms have GCFI of $350,000-$999,999. Large-scale family farms have GCFI of $1,000,000 or more.
Source: USDA, Economic Research Service and National Agricultural Statistics Service, 2013 Agricultural Resource Management Survey.

Different classes of farms account for different shares of production for different commodities. For example, small family farms account for a greater share of production of poultry, hay, and other livestock than they do for other commodities (Figure 2-5). Midsize family farms account for a greater share of cash grain/soybean and hog production than they do for other commodities. Large family farms play a particularly large role in the production of cotton, dairy, high value crops, and hogs. The proportion of production contributed by nonfamily farms is largest in high value crop, dairy, and beef production (Hoppe, 2014).

Figure 2-5. Share of the value of production from small family farms , for selected commodities, 2013



*Includes barley, corn, grain sorghum, rice, soybeans, wheat, and oats.
**Includes vegetables, fruit/tree nuts, and nursery/greenhouse products.
Note: Small family farms have annual gross cash farm income (GCFI) < $350,000.
Source: USDA, Economic Research Service and National Agricultural Statistics Service, 2013 Agricultural Resource Management Survey.

Farm operations can be divided into three categories of tenure: full owner, where the operation owns all the land farmed; part owner, where the operation owns some of the land and rents the rest; and tenant, where the operation essentially rents all the land operated. Large majorities of small family farms and nonfamily farms are full owners. Leasing is most common among family farms with Gross Cash Farm Income of at least $150,000, in other words moderate sales, midsize, large, and very large farms. In each of these categories between 55 and 73 percent of the farms are part owners, and an additional 12 to 20 percent are tenants (Hoppe 2014).

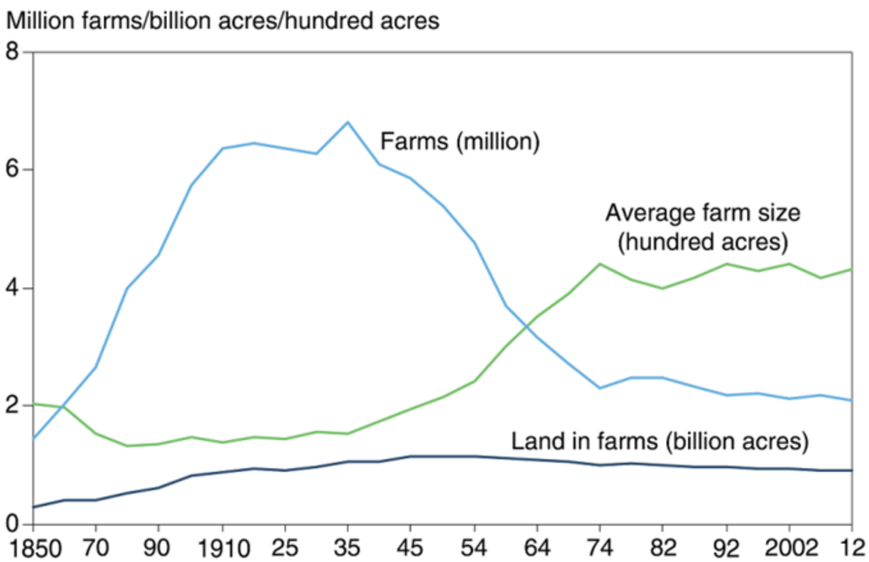
The average age of principal farm operators in the United States has been high for years, and it has been increasing over time. According to the U.S. Department of Agriculture's Census of Agriculture, during the last 30 years, the average age of U.S. farmers has grown by nearly eight years, from 50.5 years to 58.3 years.

In the United States, principal farm operators are predominantly white and male. Racial minorities accounted for about 4-5 percent and Hispanics about 3 percent of all principal operators in 2012, and similar percentages for each farm type. Men are the principal operators of over 85 percent of all farms and essentially all family farms with Gross Cash Farm Income of $150,000 or more. Women-operated farms tend to be small. Of farms operated by women, 95 percent are classified as retirement, off-farm occupation, or low-sales farms (USDA NASS 2014; Hoppe 2014).

Nonetheless, the percent of farms operated by women in the United States, only about 5 percent in 1978, has increased over time to nearly 14 percent in the last two Agricultural Censuses. Furthermore, even though most farms with women as principal operators are in small sales classes, the number of women-operated farms has increased in all sales classes. If both principal and secondary operators are counted, the number of women operators in 2012 expands from nearly 300,000 to nearly 1 million (USDA NASS 2014; Hoppe and Korb 2013).

Although the vast majority of U.S. farms consist of family-owned and operated farms, there has been considerable consolidation and movement to larger farm size over time. A long term historical perspective shows that the number of U.S. farms peaked in the 1930s and then fell rapidly until the mid-1970s. Since then, the decline in farm numbers has been slower, and average farm size, which also rose between the 1930s and the 1970s, has risen more slowly since (Figure 2-6).

Figure 2-6. Farms, land in farms, and average acres per farm, United States 1850-2012.



Source: USDA, Economic Research service using data from USDA, National Agricultural Statistics Service, Census of Agriculture.

Average farm size conceals other estimates that indicate even further consolidation of U.S. farm production over time. Table 2-3 presents mid-point acreages for selected field crops in 1987 and again in 2012, and Table 2-4 presents mid-point acreages for selected high-valued crops—vegetables and tree crops—over the same period of time. The midpoint acreage is the enterprise farm size, in harvested acres, at which half of all harvested acres are on larger enterprises, and half are on smaller enterprises. The measure of midpoint acreage represents an enterprise, the part of the farm producing the commodity in question. For example, a farm producing corn and soybeans has a corn enterprise and a soybean enterprise. The midpoint acreage for corn represents harvested corn acreage only, not harvested acreage of all crops on farms producing corn.

Table 2-3. Changes in harvested acreage for field crops, 1987-2012

Commodity (field crops)	1987	2012
	Midpoint acreage, harvested acres	
Corn	200	633
Soybeans	243	567
Wheat	404	1,005
Cotton	450	970

Note: Midpoint acreages are the enterprise farm size, in harvested acres, at which half of all harvested acres are on larger enterprises, and half are on smaller enterprises.
Source: MacDonald and Marion (2015), based on ERS calculations from unpublished Census of Agriculture records, 1987 and 2012.

Table 2-4. Changes in harvested acreages for selected high-value crops, 1987-2012

Commodity	1987	2012
	Midpoint acreage, harvested acres	
Vegetables		
Asparagus	160	200
Lettuce	949	1,275
Potatoes	350	1,054
Sweet corn	100	300
Tomatoes	400	930
Tree crops		
Apples	83	179
Almonds	203	547
Oranges	450	1,335

Note: Midpoint acreages are the enterprise farm size, in harvested acres, at which half of all harvested acres are on larger enterprises, and half are on smaller enterprises.
Source: MacDonald and Marion (2015), based on ERS calculations from unpublished Census of Agriculture records, 1987 and 2012.

The midpoint acreage for corn more than tripled from 1987 to 2012, while the midpoint acreages for cotton, soybeans and wheat more than doubled over the same period. There was a greater range of changes for midpoint acreages of high-valued crops between 1987 and 2012. For example, for several commodities not reported in Table 6, midpoint acreages declined, and for several others they showed little change. However for most high-valued crops, midpoint acreages increased quite substantially.

Comparable estimates for livestock are presented in Table 2-5. For meat animals and poultry, USDA researchers measured midpoint size for annual sales or removals. This measure is the enterprise size, in number of head removed or sold, at which half the total animals are on larger enterprises and half the total on smaller enterprises. For dairy cows, midpoint size was measured based on herd inventory. For dairy, half the cows were in herds greater than the midpoint size and half the cows were in smaller herds. As with crops, changes in midpoint size for livestock were, in general, large. Shifts to larger livestock operations were most striking for hogs and dairy. The midpoint size for hog production was 1,200 in 1987 and 40,000 in 2012. Between 1987 and 2012, midpoint milk cow inventories on U.S. dairy farms increased more than tenfold.

Table 2-5. Consolidation in livestock production, 1987-2012

Commodity (livestock)	1987	2012
	Midpoints	
	Annual Head Removed or Sold	
Broilers	300,000	680,000
Hogs	1,200	40,000
Fattened cattle	17,532	38,369
Cattle, <500 lbs.	50	200
	Milk cow inventory	
Dairy	80	900

Note: The midpoint is defined as the enterprise size, in number of head, at which half of animals are on larger enterprises and half are on smaller enterprises.
Source: MacDonald and Marion (2015), based on ERS calculations from unpublished Census of Agriculture records, 1987 and 2012.

For both U.S. crop and livestock farms, drivers of consolidation include technology, changes in farm organization, and government policy. As noted earlier, family farms still dominate U.S. agricultural production, and “there is no evidence of any systematic decline in family operations.” Some factors, such as the financial risk associated with the land and capital requirements for large scale farming, or new precision technologies that reduce managerial diseconomies associated with hired managers and labor, may eventually threaten family farm viability. As long as family farms are able to limit and manage financial risks, and as long as the strengths of family organization—such as localized knowledge and flexible adjustments to changed circumstances—remain necessary, they will continue to dominate U.S. agricultural production (MacDonald et al. 2013).

3. Major Drivers of Biodiversity Change related to Food and Agriculture

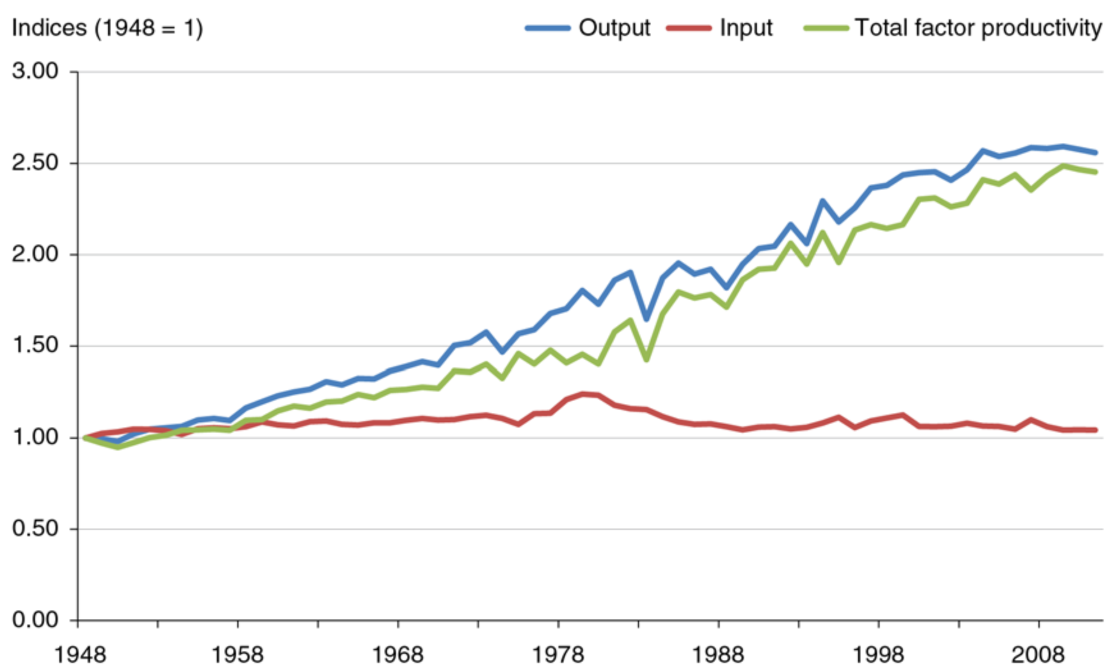
A large number of factors influence biodiversity composition and health. Here, eleven potential drivers of biodiversity change impacting on and impacted by food and agriculture are considered: productivity growth, pesticide use, fertilizer use, conservation tillage, crop rotation and cover crops, irrigation, livestock production practices, biofuels, biotechnology, climate change, and agroforestry. The interaction of drivers and other factors make it difficult to attribute biodiversity change to any single driver.

3.1 Productivity growth

Technological developments in agriculture have been particularly important in driving change in the U.S. farm sector. Agricultural output can increase both through greater use of agricultural inputs such as fertilizer, or through the adoption of new technology such as new crop varieties, better animal husbandry, improvements in machinery and chemicals, or enhancements to irrigation technology. Improving total factor productivity (TFP)—a measure of the effect of technology changes and the improved use of inputs—can substitute for resource expansion and input intensification to raise agricultural output.

As reported in Wang et al. (2015), between 1948 and 2011, U.S. agricultural output grew at 1.49 percent per year. With little growth in total input use (0.07 percent per year) during the period, the extraordinary performance of the U.S. farm sector was driven mainly by productivity growth, at an annual rate of 1.42 percent as measured by TFP (figure 3-1).

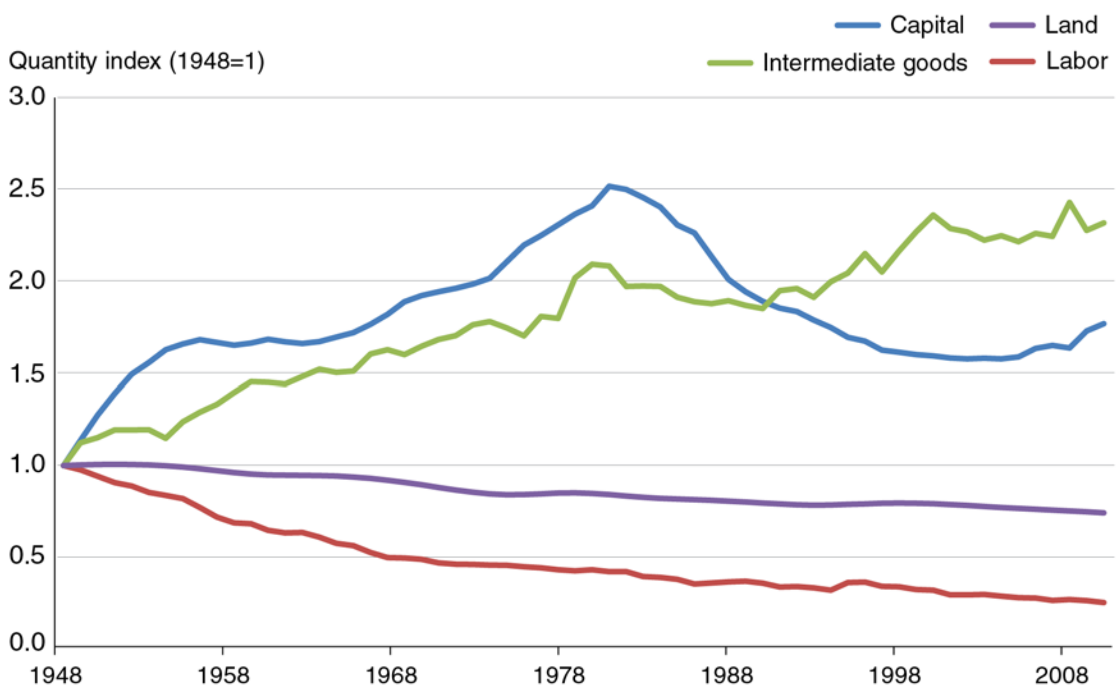
Figure 3-1. Agricultural productivity growth between 1948 and 2011



Source: USDA, Economic Research Service productivity accounts.

Wang et al. (2015) further find that among the four major input categories—labor, capital, intermediate goods (such as fertilizer, pesticides, and purchased services), and land—only capital and intermediate goods showed long-term positive growth, with average annual growth rates of 0.8 percent and 1.27 percent, respectively (Figure 3-2). During the same period, land input dropped by 26 percent, or 0.5 percent per year, while labor use declined much more sharply by 78 percent, or 2.41 percent per year. In addition to being replaced by machinery and agricultural chemicals, over the last two decades, farm labor input has also been replaced by purchased contract labor services, which are included as part of purchased services in intermediate goods. (Wang et al. 2015).

Figure 3-2. Change in major production inputs between 1948 and 2011



Source: USDA, Economic Research Service productivity accounts.

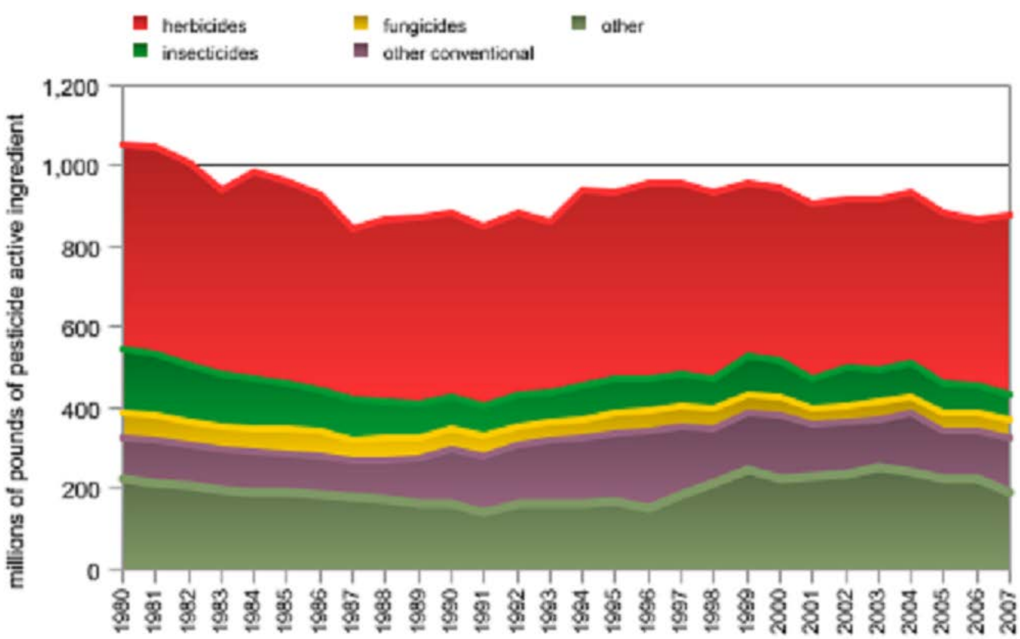
TFP growth is largely recognized as providing a strong opportunity for reducing environmental externalities from agriculture (see for example, WRI 2014). By increasing overall efficiency, TFP growth can reduce agriculture's environmental footprint and provide benefits such as halting forest-to-cropland conversion and reducing greenhouse gas emissions per ton of meat and milk output. However, TFP growth does not explicitly measure environmental impacts, nor does it necessarily lead to environmental improvements.

Adoption of new precision agricultural technologies has potential to further increase productivity and reduce input use through more precise application of inputs. The main precision agriculture technologies are yield monitors, variable-rate applicators, and Global Positioning System (GPS) maps. Adoption of these technologies in the United States was mixed during the most recent period for which detailed data are available, with the use of yield monitors reported on 40 to 45 percent of U.S. corn and soybean area in 2005-2006. Use of GPS monitors and variable rate technologies was higher on corn and soybeans grown in the Corn Belt than elsewhere, but still relatively low compared to yield monitor use. Nationally, in 2005-2006 variable rate technologies were used on only 12 percent of the corn area and 8 percent of the soybean area (Schimmelpfennig and Ebel 2011).

3.2 Pesticide use

From 1980 to 2007, total pesticide use in the United States, as measured by quantities of active ingredients, fell by about 20 percent (Figure 3-3). These changes conceal different patterns for different crops and relationships with other technical changes. Five crops—corn, cotton, fall potatoes, soybeans, and wheat—account for nearly two-thirds of pesticide quantities applied (O'Donoghue et al. 2011). Total pesticide use on these crops was generally stable but varied from year to year during these years. Increased use of herbicide-tolerant corn, soybean, and cotton varieties resulted in changes in herbicide application rates, increased use of the herbicide glyphosate, and a shift away from more toxic herbicides (National Research Council, 2010). Adoption of Bt varieties of corn and cotton resulted in reductions in insecticides applied to these crops.

Figure 3-3. Pesticide active ingredients applied by U.S. Agricultural Producers, 1980-2007

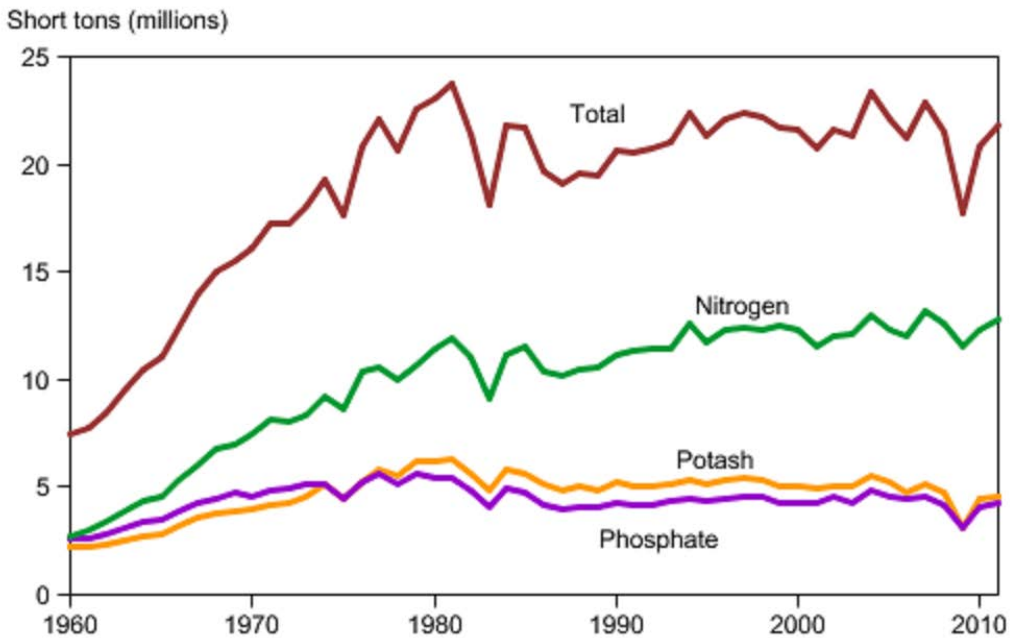


Source: Estimates for 1980-1987 are from Donaldson et al., and the estimates for 1988-2007 are from Grube et al.

3.3 Fertilizer use

Total fertilizer use in U.S. agriculture rose rapidly during the period from 1950 to 1980, after which it leveled off. Since 1980, nitrogen use has increased at a more modest rate while phosphate and potash use declined slightly (Figure 3-4). U.S. farmers have been moving away from multiple-nutrient fertilizers toward single-nutrient fertilizers or fertilizers with a high level of nutrient concentration. Corn receives the most fertilizer and the most nitrogen. Manure can also be used as a source of nutrients, and in principle, manure use on crops could play a larger role in the management of waste from livestock production. In 2006, manure was spread on just 5 percent of planted area. Corn accounted for just under 60 percent of manured acreage (MacDonald et al. 2009).

Figure 3-4. Fertilizer Use in U.S. Agriculture, 1960-2011



Source: USDA, Economic Research Service, using data from Association of American Plant Food Control Officials and The Fertilizer Institute.

3.4 CONSERVATION TILLAGE

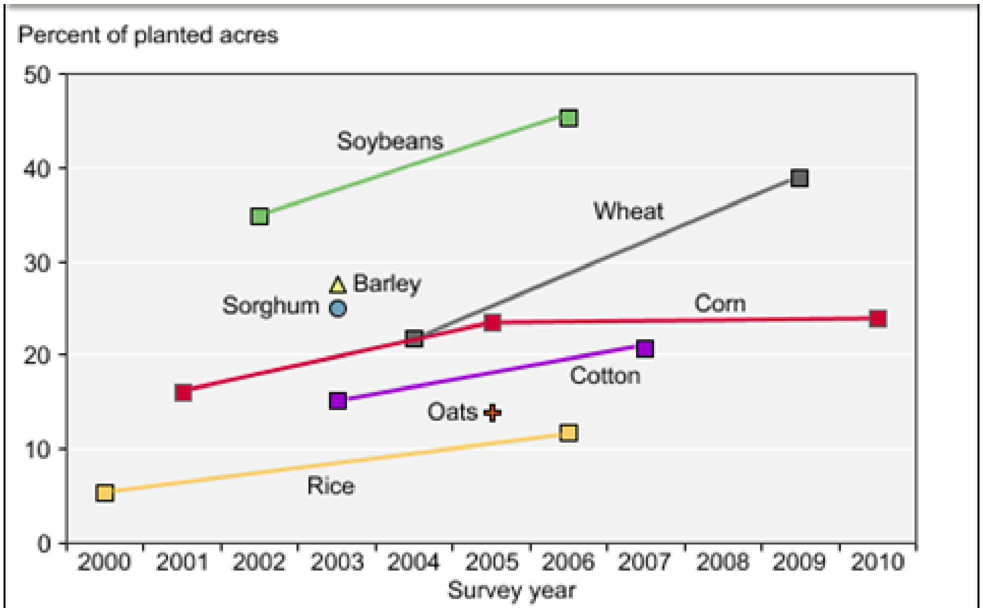
From Wallander (2013)

Tillage—turning the soil to control for weeds and pests and to prepare for seeding—has long been part of crop farming. However, intensive soil tillage can increase the likelihood of soil erosion, nutrient runoff into nearby waterways, and the release of greenhouse gases into the atmosphere. A reduction in how often or how intensively cropland is tilled enables the soil to retain more organic matter, which leaves the soil less susceptible to wind and water erosion and helps store, or "sequester," carbon. Intensive tillage triggers spurts of activity among bacteria and other organisms that consume organic matter (converting it to CO_2), depleting the active fraction first. Practices that build soil organic matter (e.g., reduced tillage and regular additions of organic material) will raise the proportion of active organic matter long before increases in total organic matter can be measured (Tugel *et al*. 2000). Increased soil organic matter can provide improved habitat soil biologic activity.

No-till is generally the least intensive form of tillage; no-till operations accounted for an estimated 35 percent of U.S. cropland planted to eight major crops in 2009. The crops—barley, corn, cotton, oats, rice, sorghum, soybeans, and wheat—constituted 94 percent of total U.S. planted acreage in 2009. Furthermore, the use of no-till increased over time for corn, cotton, soybeans, and rice, the crops for which the Agricultural Resource Management Survey (ARMS) data were sufficient to calculate a trend.

No-till adoption varied substantially across crops, however, even for those that have generally similar production practices (Figure 3-5). For example, land planted to barley had roughly twice the percentage of no-till (28 percent in 2003) as land planted to oats (14 percent in 2005).

Figure 3-5 Percentage of planted acres under no-till system for selected crops, 2000-2010



Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, Phase 2, 2000-2010.

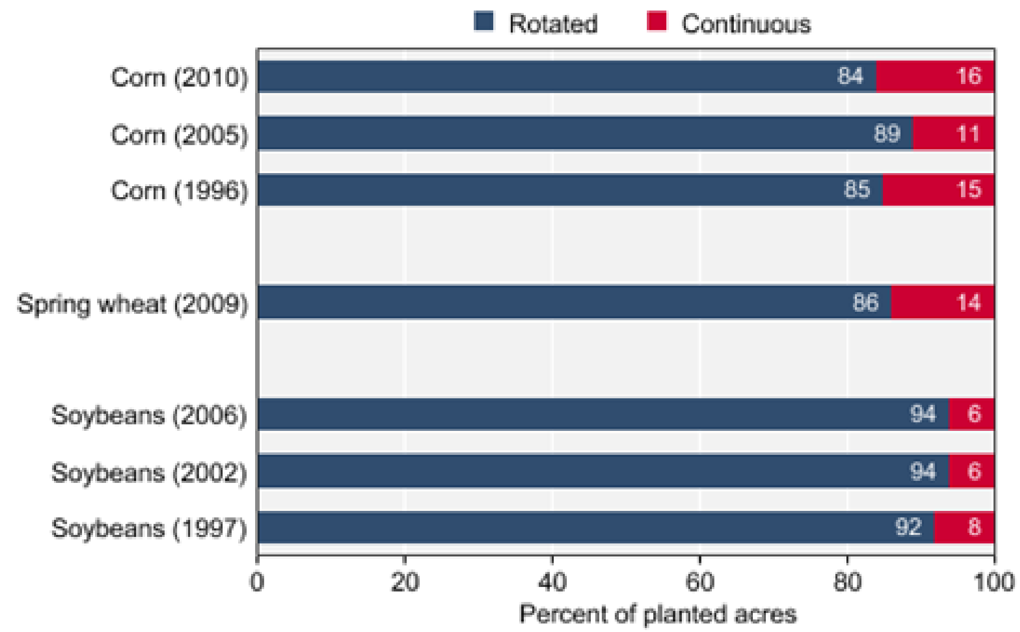
3.5 Crop rotation and cover crops

From Wallander (2013)

Crop rotations are planned sequences of crops over time on the same field. Rotating crops provides productivity benefits by improving soil nutrient levels and breaking crop pest cycles. Conservation crop rotations, particularly those rotations that incorporate cover crops, are production systems that are planned to also produce important environmental benefits such as reduced soil erosion, increased carbon sequestration, improved wildlife habitat, or improved water quality.

One indication of how prevalent crop rotations are in U.S. production is how relatively rare it is for farms to continuously produce the same crop from year to year on the same field. For corn, soybean, and wheat, between 84 and 92 percent of acreage involves some sort of rotation (Figure 3-6).

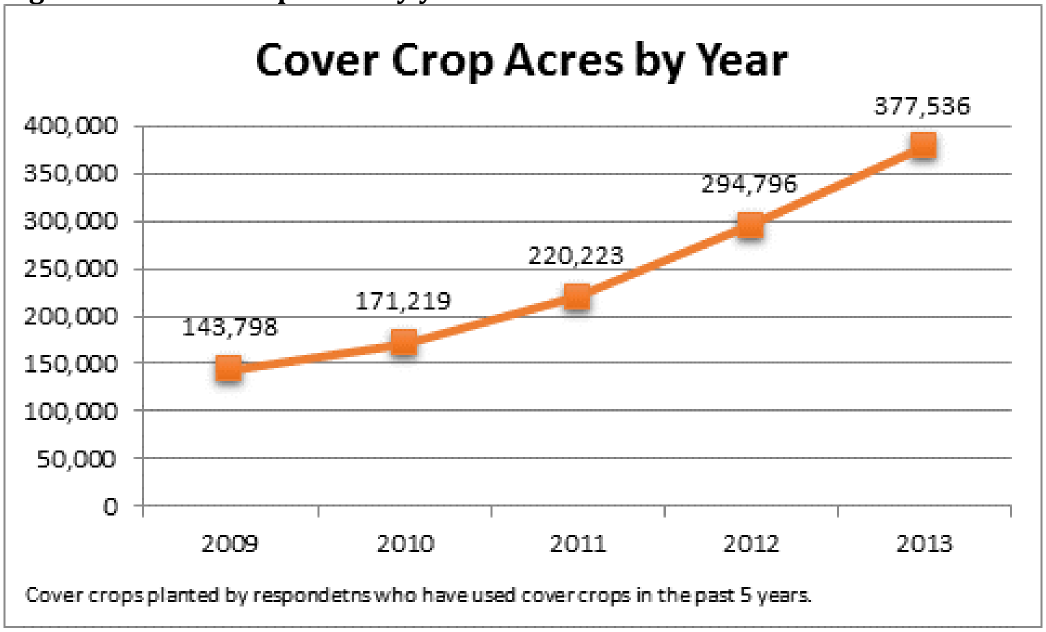
Figure 3-6. Percent of planted acres under rotated and continuous plantings for selected crops, 1997-2010



Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, Phase 2, 1996-2010.

While crop rotations are prevalent, conservation crop rotations that incorporate cover crops remain rare. Only about 3 to 7 percent of farms use cover crops in rotations, and, since these operations do not put all of their land into cover crops, only 1 percent of cropland acreage uses cover crops. However, adoption of cover crops continues to increase. Figure 3-7 shows that cover crop adoption has gone from fewer than 150,000 acres per year in 2009 to nearly 380,000 acres a year in 2013.

Figure 3-7 Cover crop acres by year



Source: CTIC 2014

3.6 Water Management and Irrigation

Agricultural drainage plays an important role in water quality and hydrological conditions. Drainage systems (tile in particular) move soluble nutrients directly into waterways. They also accelerate water movement increasing peak flows.

(From USDA ERS (2013a) and USDA NASS (2014)

Agriculture is a major user of ground and surface water in the United States, accounting for approximately 80 percent of the Nation's consumptive water use and over 90 percent in many Western States. Efficient irrigation systems and water management practices can help maintain farm profitability in an era of increasingly limited and more costly water supplies. Improved water management practices may also reduce the impact of irrigated production on offsite water quantity and quality, and conserve water for growing nonagricultural demands.

In 2012, irrigated farms in the United States accounted for about 50 percent of the total value of crop sales while also supporting the livestock and poultry sectors through irrigated production of animal forage and feed crops. At the same time, only one-sixth of harvested cropland in 2012 was irrigated. Traditionally most of the irrigated area was in the 17 western-most contiguous states, and these states still accounted for over 70 percent of irrigated farmland in 2012. Over the past 30 years, irrigation has also expanded along the lower reaches of the Mississippi River, where irrigated land in 2012 constituted about 15 percent of the U.S. total. Irrigated land has also expanded in Florida and Georgia.

3.7 Livestock and poultry production practices

A brief characterization of livestock production practices in the United States is difficult because of differences across species, as well as the wide variety of circumstances under which livestock production occurs. Beef cow-calf operations are often extensive, contrasting with intensive confined animal feeding operations (CAFOs) for feedlot beef, dairy, hogs, and poultry. In recent years declines in numbers of livestock operations have been accompanied by production shifts towards cost-saving production technologies and practices. USDA's Economic Research Service uses information from the Agricultural Resources Management Survey (ARMS) and the Agricultural Census to describe changes in production practices (MacDonald and McBride 2009; MacDonald et al. 2007; McBride and Mathews 2011; McBride and Key 2013; MacDonald 2014).

Hog finishing provides an example of the relationship between both size of operation and type of operation and livestock production practices in the United States. Market hogs are produced on either farrow-to-finish or feeder pig-to-finish operations. On farrow-to-finish operations pigs are farrowed and raised to slaughter weight. On feeder pig-to-finish operations, feeder pigs from between 30 to 80 pounds are either purchased or placed under contract from outside the operation, and then raised to slaughter weight. Use of certain breeding practices, such as artificial insemination, increases markedly with operation size for farrow-to-finish operations. On both types of operations phase feeding (matching animal diets with changing nutritional requirements) also varies with farm size, as does all-in/all-out finishing, in which pigs of similar age and weight are kept together as they move through each production phase. In general, use of these management practices is higher regardless of farm size on feeder pig-to-finish than on farrow-to-finish operations (Table 3-1).

Table 3-1 Production Practice Use by Size and Type of U.S. Hog Producer, 2004

	Size of operation[1]			
Item	**Fewer than 500 head**	**500-1,999 head**	**2,000-4,999 head**	**5,000 head or more**
	Percent of farms			
Farrow-to-finish operations				
Artificial insemination	4	12	51	92
Terminal crossbreeding	11	38	43	73
Commercial seed stock	5	24	36	26
Phase feeding	42	53	61	84
All-in/all-out finishing	14	20	54	83
Feeder pig-to-finish				
Phase feeding	51	60	72	72
All-in/all-out finishing	66	80	86	92

[1]Size of operation is the maximum number of hog and pigs on the operation at any time during 2004.
Source: USDA, ERS using data from the 2004 Agricultural Resources Management Survey

The growth of CAFOs in the United States has triggered concern about environmental impacts of this practice. Using USDA data for large farms that raise animals as a proxy for CAFOs, the U.S. Government Accountability Office, estimated that the number of CAFOs increased by about 230 percent, increasing from about 3,600 in 1982 to almost 12,000 in 2002 (USGAO 2008). According to the U.S. Environmental Protection Agency (EPA), concentration of the wastes from CAFOs increases the potential to impact air, water, and land quality (USEPA 2014b). Manure and wastewater have the potential to contribute pollutants, such as nitrogen and phosphorus, organic matter, sediments, pathogens, heavy metals, hormones and ammonia, to the environment. The environmental impacts resulting from mismanagement of wastes include, among others, excess nutrients in water (such as nitrogen and phosphorus), which can contribute nuisance and toxic algal blooms, as well as contributing to low levels of dissolved oxygen as organic matter decomposes, which can in turn lead to fish kills. Contamination from runoff or lagoon leakage can degrade water resources, and can contribute to illness by exposing people to wastes and pathogens in their drinking water. Dust and odors can contribute to respiratory problems in workers and nearby residents (USEPA 2014b).

Concerns about environmental impacts of CAFOs are helping to drive change. In 2008, the U.S Government charged the EPA with developing a national inventory of permitted CAFOs in order to more effectively monitor and regulate them. In 2012, EPA signed a memorandum of understanding with the Association of the Clean Water Administrators (ACWA) to facilitate the exchange of information. This collaborative effort between the EPA and ACWA will focus on identifying CAFOs and obtaining pertinent information about CAFOs on a state-by-state basis for use by both ACWA members and the EPA.

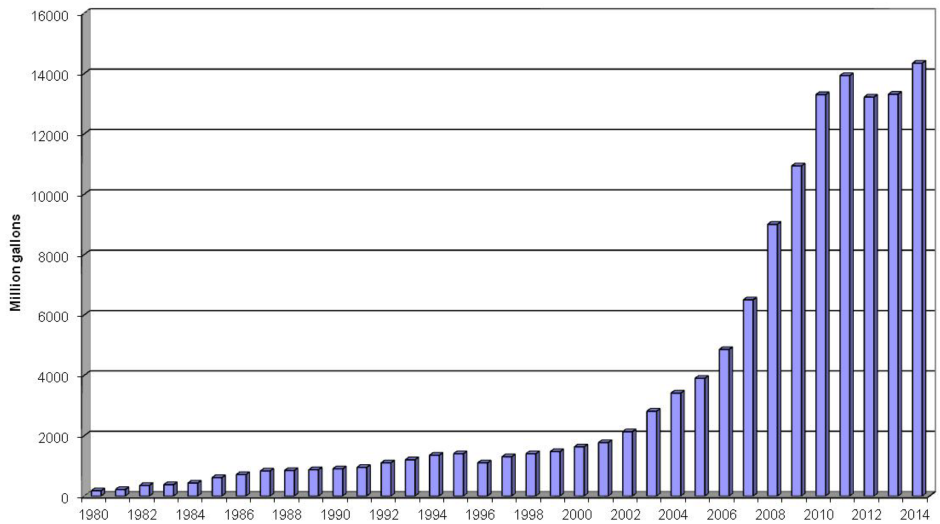
Key et al. (2011) found that between 1998 and 2009, hog farm operators altered their practices in ways that suggested their intent to manage manure in a more environmentally sound manner. These included adoption of comprehensive nutrient management plans, addition of feed additives to reduce phosphorus in hog manure, and attempts to balance manure application to crops with the nutrient needs of those crops. These changes in practices were related to increases in farm size and regional shifts of production. Environmental policies designed to reduce overapplication of manure nutrients may have also influenced hog operations, particularly larger ones, to alter their manure management practices.

While CAFOs present an environmental challenge, evidence points to environmental benefits of efficient meat production. By improving efficiencies, modern livestock production can lead to reductions in the number of animals needed to satisfy nutritional demands. Capper et al. (2009) suggest that in the United States, continued improvement of management systems and technologies would reduce resource use and environmental impact without sacrificing production. When comparing 1944 with 2007 dairies in the United States, Capper et al. (2009) found that modern dairies require 21 percent of animals, 23 percent of feedstuffs, 35 percent of the water, and 10 percent of the land to produce the same quantity of milk. Emissions have also been reduced since 1944; dairies today produce 43percent of CH_4 and 56 percent of N_2O per unit. Pitesky et al. (2009) find that intensification of livestock production provides large opportunities for climate change mitigation and can reduce greenhouse gas emissions from deforestation, thus becoming a long-term solution to a more sustainable livestock production.

3.8 Biofuels

Since 2000, the biofuels industry has shown tremendous growth in the United States – ethanol production increased from 1.6 billion gallons to more than 14.0 billion gallons in 2014 (Figure 3-8). Similarly, biodiesel fuel has also shown remarkable growth from fewer than 5 million gallons in 2000 to 1.3 billion gallons in 2014. Ethanol is the dominant biofuel produced and used in the United States.

Figure 3-8. U.S. Ethanol Production, 1980-2014



Source: Energy Information Administration

Biomass used for biofuels production remains predominantly corn based for ethanol, and vegetable oils and fats for biodiesel. Since the growth in biofuels production in the United States, total cropland use has declined, acreage in the Conservation Reserve Program has dropped, and acreage devoted to corn and soybeans have increased.

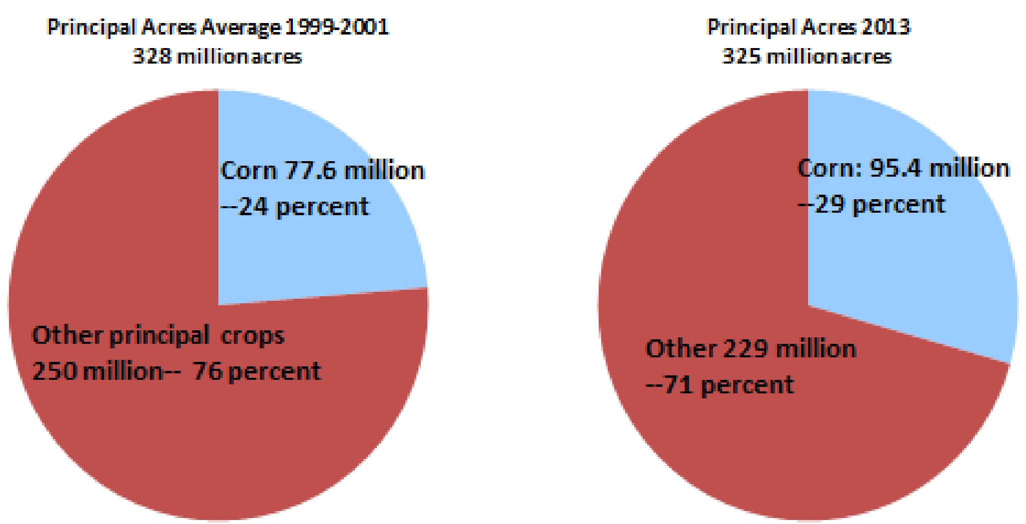
U.S. corn output has increased substantially over the last several decades, reflecting steady productivity gains and, more recently, increases in planted area. In 2013, U.S. producers planted 95.4 million acres of corn (38.6 million hectares), down 1.9 million acres from 2012, when acreage set a post-World War II high of 97.3 million acres. From 2000 through 2005, corn acreage planted averaged around 79 million acres per year, and then jumped dramatically to 93.5 million in 2007. Farmers reacted to record high prices and very strong net returns for corn. Since the big expansion in ethanol use, plantings have averaged 91.2 million acres per year (2007 through 2013).

While some producers will grow corn on the same acres in successive years, corn will most commonly be rotated with soybeans, with acreage adjustments often based on the expected price ratio between those two crops. Soybean area has also increased, although on a more modest scale than corn, with one dramatic exception in 2007 when corn surged by more than 15 million acres (19 percent) in response to strong price signals triggered by unprecedented demand. Simultaneously, soybean acres shrank by 10.8 million acres (14 percent), an indication of the willingness of U.S. farmers to respond to changes in relative prices.

Much of the recent acreage gains in corn and soybeans since 2005 reflect land switching from other crops and hay land. Some of the production of these crops and hay expanded to land exiting the Conservation Reserve Program (CRP). Land in the CRP is put in a conserving use such as grass or trees and is not available for crop production over a 10 or 15 year period. Much expiring CRP land is marginal cropland located in drier regions and not well suited for corn, but is more favorable for grass or possibly wheat. Expired CRP land freed up additional acres for hay or wheat, allowing other acres previously growing these crops to be planted to corn and soybeans.

The increase in corn plantings has been widespread with large gains in the traditional leading corn producing states such as Iowa, Illinois, Nebraska, and Minnesota. The biggest increases among states were in the Dakotas, while Kansas also had substantial increases. Reductions in wheat, barley, hay, and sorghum area account for much of the increase of corn and soybeans in these states. Nationally, the area planted to principal crops began to rebound after 2006, but the 2013 total remains lower than the average for 1999-2001, although corn's share of plantings has increased (Figure 3-9).

Figure 3-9. Corn area as a share of principal crop acres, 1999-2001 and 2013



<u>Environmental Impacts of Biofuels</u>

The Department of Energy (DOE) released in 2005 a report entitled *Biomass as Feedstock for a Bioenergy and Bioproduct Industry: The Technical Feasibilty of a Billion-Ton Annual Supply* (US DOE 2005). This study, which provides an accounting of the available biomass in the United States, became known as the Billion Ton Study (BTS). It concluded that sufficient forestland and agricultural land, the two largest potential biomass sources, could produce over 1.3 billion dry tons per year of biomass potential, enough to produce biofuels to meet more than one-third of the 2005 demand for transportation fuels. The full resource potential could be available roughly around mid-21st century when large-scale bioenergy and biorefinery industries are likely to exist.

The BTS was updated in 2011 in the report *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry* (referred to as the BTS-U) (US DOE 2011). This update also concluded that there is more than a billion tons of biomass available for use in bioenergy and biobased manufacturing in the United States. The BTS-U expands on the 2005 BTS to include a spatial, county-by-county inventory of potentially available primary feedstocks; price and available quantities (e.g., supply curves) for the individual feedstocks; and a more rigorous treatment and modeling of resource sustainability.

A second update of the "billion-ton" work is planned for release in 2016 (BT16). This report will be released in two volumes. Volume 1 will focus on resource analyses, report supplies as a function of price, both at the farmgate and delivered to the biorefinery, will include new feedstocks (e.g., algae, Miscanthus, eucalyptus), and describe commercialization strategies. BT16 Volume 2, targeted for publication in the fourth quarter of 2016, will concentrate on environmental sustainability, climate change impacts, strategies to enhance environmental sustainability, and attempts to quantify the environmental effects of potential biomass supply identified in Volume 1, with the intent of moving toward quantifying sustainable biomass supply in the United States.

Environmental assessments and environmental sustainability indicators under alternative biomass supply scenarios will be discussed for soil quality (soil organic carbon), water quality and quantity (nitrate loadings, total P loadings, suspended sediment loadings, water yield), air quality (PM2.5, PM10, carbon monoxide, volatile organic compounds, sulfur oxides, nitrogen oxides), greenhouse gas emissions (CO2, CH4, N2O, black carbon, CO2e), and biodiversity (implications of future bioenergy landscapes on habitat for taxa of concern, specifically birds).

For the analysis of biodiversity impacts, the U.S. Department of Energy (DOE) is developing science-based methods to evaluate bird diversity at a National scale under selected future economic bioenergy landscapes (POLYSYS scenarios). The approach builds on a previous study (Evans et al. 2014) that assumed a negative effect of bioenergy crops on habitat. However, DOE's approach will account for the habitat value of perennial crops by assuming that collections of parcels with suitable habitat must exceed a species-specific minimum habitat area. Habitat value will be estimated from published data comparing bird densities in other crops or land uses to those in switchgrass fields (e.g., Uden et al. 2015) or woody biomass plantations (e.g., Riffell et al. 2011).

<u>Policy Drivers of Biofuel Expansion</u>

Tax credits, excise taxes, import policies, financial (loan) incentives and other energy related policies helped ethanol production grow at a slow, but steady pace throughout the 1970s and 1980s. However, ethanol production received a major boost in the 1990s when environmental policies began to play a larger role in the industry's development. The first environmental policy to have a major effect on renewable energy was the Clean Air Act Amendments of 1990 (CAA). Provisions of the CAA established the Oxygenated Fuels Program and the Reformulated Gasoline (RFG) Program to control carbon monoxide and ozone problems in certain urban areas around the country. Both program fuels required the addition of oxygen compounds to gasoline, and blending ethanol became a popular method for gasoline producers to meet the new oxygen requirements mandated by the CAA (Unzelman 1992). The oxygenate requirement increased the demand for ethanol significantly but the preferred oxygenate at the time was a petroleum product called methyl tertiary butyl ether (MTBE).

In 1999, ethanol production received a major boost when it was announced that California would ban the use of MTBE because of water contamination (McCarthy and Tiemann 2006). The State of California made a formal request to EPA for a waiver from the requirement to use oxygenates in reformulated gasoline, so refineries would not be forced to add oxygenates to their gasoline. Two years later, in June 2001, EPA denied California's request and the only other oxygenate available to the State was ethanol. As the phase-out of MTBE in favor of ethanol began in California, at least 24 other states followed suit, creating a 5.0 billion gallon void in the oxygenate market (McCarthy and Tiemann 2006). Ethanol capacity began to expand very quickly to meet this new demand, becoming the dominant fuel additive in the Oxygenated Fuels Program and the Reformulated Gasoline Program.

Starting in the late 1990s, farm legislation also started to direct attention towards renewable energy expansion. A provision in the Department of Agriculture's FY 2000 Appropriations Act authorized the establishment of pilot projects for harvesting biomass on lands set aside from crop production under the Conservation Reserve Program (CRP) (Duffield and Collins 2006). USDA also initiated the Commodity Credit Corporation (CCC) Bioenergy Program to stimulate demand and alleviate crop surpluses, which were contributing to low crop prices and farm income, and to encourage new production of biofuels. USDA made cash payment to eligible ethanol and biodiesel producers who expanded yearly production. Most of the funds went to ethanol plants, which were expanding at the time to meet new demand from the RFG and octane markets. The link between renewable energy and agriculture was cemented with the enactment of the 2002 Farm Bill that contained the first energy title in Farm Bill history. The energy title, Title IX, created a range of programs through 2007 to promote bioenergy and bioproduct production and consumption. It included section 9010 that codified the CCC Bioenergy Program by providing up to $150 million per year in funding for fiscal years 2003 through 2006 (Duffield et al. 2008).

The 2008 Farm Bill continued to support renewable energy programs, however, most of USDA's energy programs are now aimed at advanced biofuels made from waste products, woody biomass, and other non-food sources (USDA 2010a). The energy title was reauthorized again under the 2014 Farm Bill, continuing USDA's investment in the production of renewable biomass for biofuels (USDA ERS 2014). It provided mandated funding for advanced biofuels and other biobased products. Loan guarantees, cash payments, and grants were made available for the development, construction, and retrofitting of commercial-scale facilities to encourage the production of advanced biofuels. The Biomass Crop Assistance Program (BCAP) was continued, which provides funding for establishing biomass crops for conversion to bioenergy.

Rising and more volatile oil prices that began at the end of the 1990s and continued into the 2000s sparked a renewed interest in developing Federal energy policies (U.S. Energy Information Administration 2013) and domestic alternative sources of energy, such as corn ethanol, to help increase the Nation's energy supply and exert downward pressure on surging oil prices. Congress did not pass a comprehensive energy bill until 2005. However, the American Jobs Creation Act of 2004 included several energy provisions and created the Volumetric Ethanol Excise Tax Credit (that changed the tax credit to a volumetric basis), and eliminated the restrictive blend levels that were designated by for the CAA requirements. This provided oil companies the flexibility to blend any amount of ethanol into gasoline to meet their octane and oxygenate needs, as long as ethanol did not exceed 10 percent (E10). The Act also extended the expiration date of the excise tax credit from 2007 to 2010, which eventually expired at the end of 2011.

Policymaker's support of ethanol and concerns with MTBE continued with the passage of the Energy Policy Act in 2005. For the first time, this Federal law addressed the MTBE issue and effectively eliminated its future use. The act removed the Clean Air Act's mandate to use oxygenates in reformulated gasoline (RFG), allowing refiners the option of making RFG without MTBE or ethanol, and encouraged the use of ethanol, by passing a renewable fuel standard (RFS) with biofuel production mandates. MTBE is not a biofuel, so there really was no reason for gasoline refiners to use it anymore, since they could meet both their RFG and RFS mandates with ethanol. With state bans, continued fears of liability due to water contamination, and the passage of the RFS, MTBE use was eliminated in the United States by 2006; and E10 soon became the most common motor fuel in the United States.

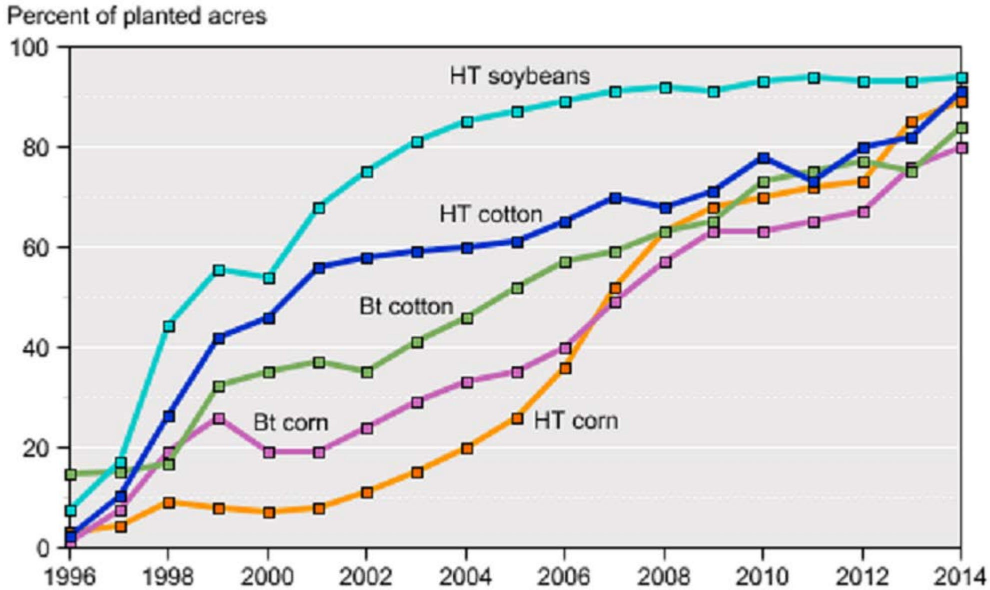
The RFS required U.S. fuel production to include a minimum amount of renewable fuel each year, starting at four billion gallons in 2006 and reaching 7.5 billion gallons in 2012. Although other biofuels qualified for the RFS, ethanol was expected to be the dominant fuel, since it already was a widely used gasoline additive. Volatile energy prices prompted Congress to pass the Energy Independence and Security Act (EISA) of 2007 (enacted December2007) aimed at reducing U.S. dependence on imported oil through an aggressive set of renewable fuel mandates referred to as the RFS2 (Federal Register, 2010). Under the RFS2, the total renewable fuel requirement was increased to 36 billion gallons per year by 2022, with a 21 billion gallon requirement for advanced biofuel (that reduce greenhouse gas (GHG) emissions by 50 percent) and a 16 billion requirement for cellulosic biofuel (that also reduce GHG by 50 percent). Cellulosic feedstocks include agricultural residues, e.g., corn stover, forestry biomass, urban waste, switchgrass, and fast growing trees. As cellulosic biofuel is also considered an advanced biofuel, it can also be used to meet the advanced biofuel requirement. The remaining 15 billion-gallons can be composed of conventional renewable fuel such as corn ethanol (that reduce GHG by at least 20 percent), though either advanced or cellulosic biofuel can compose this quantity.

Capping the renewable fuel standard requirements for corn ethanol, while increasing the mandates for advanced biofuels, reflects the intention of lawmakers to diversify the feedstocks used to produce renewable fuels. In the early years, the total renewable fuel requirement is satisfied mostly by corn-ethanol, but in 2015, advanced biofuels begin to play a more important role. By 2022, more than half of the total RFS2 must be satisfied by advanced biofuels, including 16 billion gallons of cellulosic biofuel. In order to encourage investment in advanced biofuels, Government policies and energy programs have shifted away from corn ethanol and more toward supporting the development of biofuels that use cellulosic biomass (U.S. Department of Energy, 2012).

3.9 Genetically engineered crops

U.S. farmers have widely adopted several genetically engineered crops since they were introduced in 1996. In 2014, herbicide-tolerant (HT) crops occupied 94 percent of U.S. soybean area, 91 percent of U.S. cotton area, and 89 percent of U.S. corn area. The primary herbicide tolerated by these crops is glyphosate, which is known by many trade names, including Roundup. Insect-resistant crops containing a gene or genes from the soil bacterium Bt (*Bacillus thuringiensis*) were planted on 84 percent of U.S. cotton acreage and 80 percent of U.S. corn acreage in 2014 (Figure 3-10). Other genetically engineered crops grown commercially in the United States are herbicide-tolerant canola, sugar beets, and alfalfa, and virus-resistant papaya and squash (Fernandez-Cornejo et al. 2014a).

Figure 3-10. Adoption of Genetically Engineered Crops in the United States, 1996-2014



Data for each crop category include varieties with both HT and Bt (stacked) traits.
Sources: USDA, Economic Research Service using data from Fernandez-Cornejo and McBride (2002) for the years 1996-99 and USDA, National Agricultural Statistics Service, June Agricultural Survey for the years 2000-14.

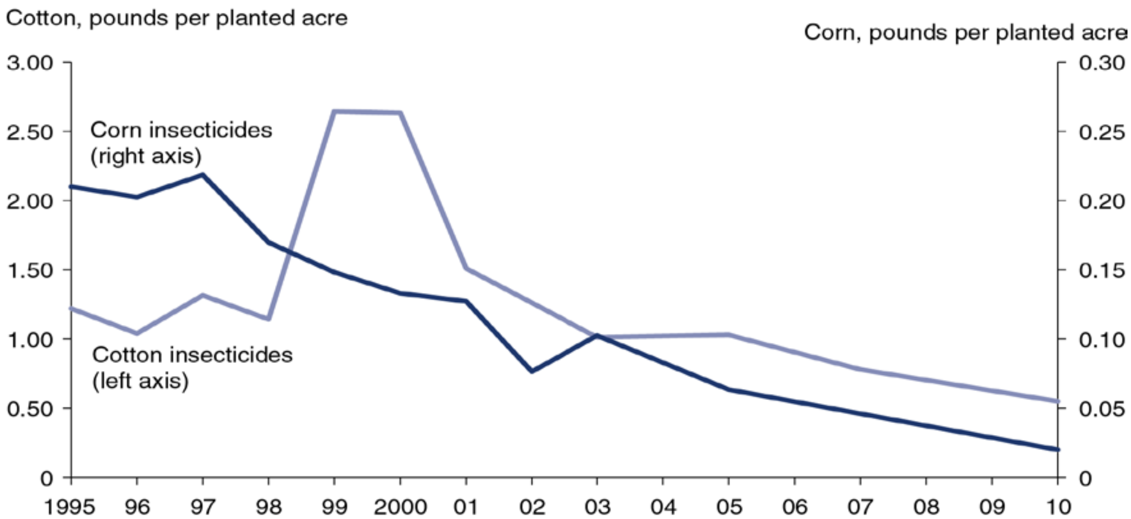
Widespread adoption of genetically engineered HT and Bt crops has triggered changes with potential impacts on biodiversity, including changes in chemical applications, increases in the use of conservation tillage, and development of herbicide-resistant weeds. These changes are examined in detail in two recent USDA reports, *Genetically Engineered Crops in the United States (*Fernandez-Cornejo et al. 2014a) and *The Economics of Glyphosate Resistance Management in Corn and Soybean Production* (Livingston et al. 2015). The section below is selectively excerpted from these two publications.

<u>GE-Crop Adoption and Pesticide Use</u>
(From Fernandez-Cornejo (2014b): 23-26)
Many studies based on field tests and farm surveys have examined the extent to which GE crop adoption affects pesticide (insecticide and herbicide) use, and most results show a reduction in pesticide use. A National Research Council study (2010) concurred that GE crops lead to reduced pesticide use and /or lower toxicity compared to conventional crops.

<u>*Insecticide use decreases with the adoption of Bt Crops.*</u> Generally, Bt adoption is associated with lower insecticide use. Pounds of insecticide (per planted acre) applied to corn and cotton crops have declined over the course of the last 15 years (Figure 3-11). (Results for cotton in 1999-2001 were distorted because of the high application rates of the insecticide Malathion during the boll weevil eradication program.) Insecticide use on corn farms declined most years and had an overall

drop from 0.21 pound per corn planted acre of corn in 1995 (the year before Bt corn was commercially introduced) to 0.06 in 2005 and 0.02 pound in 2010.

Figure 3-11 Insecticide use in corn and cotton production, 1995-2010



Source: USDA Economic Research Service using data from USDA National Agricultural Statistics Service Agricultural Chemical Usage reports.

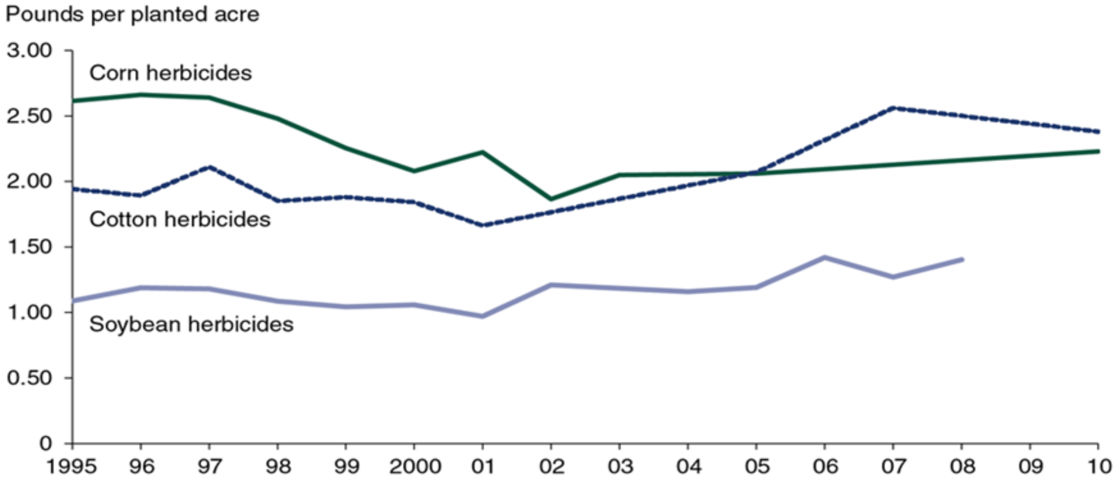
Insecticide use has declined for both Bt adopters and nonadopters in recent years. According to ARMS data, only 9 percent of all U.S. corn farmers applied insecticides in 2010. Econometric studies by ERS researchers have also found that, except for recent years, Bt crop adoption led to decreases in insecticide use, controlling for other factors. For example, Fernandez Cornejo et al. (2003) show that the adoption of Bt cotton in the Southeast region (which had higher rates of Bt adoption) was associated with lower insecticide use on cotton in 1997. After controlling for other factors, a 10-percent increase in Bt corn adoption was associated with a decrease in insecticide use of 4.1 percent in 2001 (Fernandez-Cornejo and Li 2005). However, Bt corn adoption was not significantly related to insecticide use in more recent years using 2005 data (Fernandez-Cornejo and Wechsler 2012), as well as in a new ERS analysis using 2010 survey data (see Fernandez-Cornejo et al. 2014a).

Taken together, these results suggest that insect infestation levels on corn were lower in recent years than in earlier years and are consistent with findings by Hutchinson et al. (2010) that European corn borer populations have steadily declined over the last decade. Moreover, several researchers have shown that areawide suppression of certain insects such as the European corn borer and the pink bollworm are associated with the use of Bt corn and Bt cotton, respectively (see box 3-1).

<u>*Adoption of HT crops has mixed impact on herbicide use.*</u> Herbicide use on cotton and soybean acres (measured in pounds per planted acre) declined slightly in the first years following introduction of HT seeds in 1996, but increased modestly in later years (figure 3-12). Herbicide use on soybean farms has been mostly constant since 1996, but increased slightly starting in 2002 and peaked in

2006. Herbicide use on corn fell from about 2.6 pounds per acre in the early years of HT corn adoption to less than 2 pounds per acre in 2002 but increased moderately in recent years.

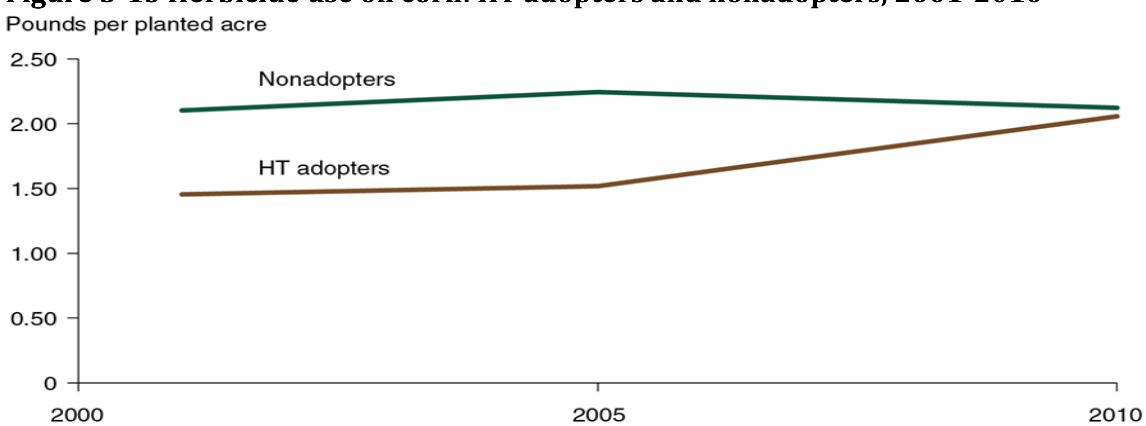
Figure 3-12 Herbicide use in cotton, corn and soybeans, 1995-2010



Data for herbicide use for soybeans in 2007 and 2008 are from proprietary data.
Source: USDA/NASS Agricultural Chemical Usage reports and USDA/NASS Quickstats.

Herbicide use on corn by HT adopters increased from around 1.5 pounds per planted acre in both 2001 and 2005 to more than 2.0 pounds per planted acre in 2010, whereas herbicide use by nonadopters did not change much (figure 3-13). HT adoption likely reduced herbicide use initially, but herbicide resistance among weed populations may have induced farmers to raise application rates in recent years, thus offsetting some of the economic and environmental advantages of HT corn adoption regarding herbicide use.[1]

Figure 3-13 Herbicide use on corn: HT adopters and nonadopters, 2001-2010



HT crops have herbicide tolerance traits.
Source: USDA Economic Research Service using data from 2001, 2005, and 2010 ARMS Phase II corn surveys.

[1] Adoption of conservation tillage by HT adopters may have also confounded these comparisons.

The main effect of HT crop adoption on herbicide use is the substitution of glyphosate for more toxic herbicides. Despite the mixed but relatively minor effect HT crop adoption has had on overall herbicide usage, most researchers agree (NRC 2010) that the main effect of HT crop adoption is the substitution of glyphosate for more traditional herbicides. Because glyphosate is significantly less toxic and less persistent than traditional herbicides (WHO 1994; NRC 2010),[2] the net impact of HT crop adoption is an improvement in environmental quality and a reduction in the health risks associated with herbicide use (even if there are slight increases in the total pounds of herbicide applied).[3] However, glyphosate resistance among weed populations in recent years may have induced farmers to raise application rates. Thus, weed resistance may be offsetting some of the

BOX 3-1 Bt crop adoption and areawide pest suppression

Hutchinson et al. (2010) show that areawide suppression of the European corn borer is associated with Bt corn use. They estimate that the cumulative benefits of Bt adoption over 14 years exceed $6 billion for corn growers in Illinois, Minnesota, Wisconsin, Iowa, and Nebraska. Non-adopters captured $4.3 billion of these benefits because they reap the rewards associated with low infestation rates without paying a premium for insect-resistant seeds. Carrière et al. (2003) conducted a 10-year study in 15 regions across Arizona and showed that Bt cotton suppressed a major pest, the pink bollworm, “independent of demographic effects of weather and variation among regions.” Pink bollworm population density declined only in regions where Bt cotton was abundant. Such long-term suppression has not been observed with insecticide sprays, suggesting that deployment of Bt crops may also contribute to reducing the need for insecticide sprays. Earlier, Marra et al. (2002) considered the side-by-side trials of Bt and conventional varieties. They discuss the bias caused by the “halo effect” that arises from the insect suppression of the Bt crops spilling over onto the conventional treatments, thus increasing the yield of the conventional crop relative to what it would be if the conventional crop were grown in isolation. This effect biases downward the yield difference between the Bt and conventional varieties. Based on data from 36 sites in 6 provinces of northern China over 1990-2010, Lu et al. (2012) found that there was an increase in beneficial insects (such as ladybirds and lace-wings) and a decrease in pests (aphids) associated with the widespread use of Bt cotton reducing insecticide sprays.

economic and environmental advantages of HT crop adoption regarding herbicide use. Moreover, herbicide toxicity may soon be negatively affected (compared to glyphosate) by the introduction (estimated for 2014) of crops tolerant to the herbicides dicamba and 2,4-D.

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[2] However, recent publications have raised questions regarding the toxicity of glyphosate. Seralini et al. (2012) claim that GE corn and low levels of glyphosate herbicide formulations at concentrations well below officially-set safe limits induce severe adverse health effects, such as tumors, in rats. But a review of the study by the European Food Safety Authority (EFSA, 2012) concluded the Seralini et al. study as reported in the publication “is inadequately designed, analyzed and reported” and is “of insufficient scientific quality for safety assessments. As a result, the EFSA states that “conclusions cannot be drawn on the difference in tumour incidence between treatment groups on the basis of the design, the analysis and the results as reported.” In a separate study, Mesnage et al. (2012) find that while toxicity of glyphosate has been safety tested on mammals, another ingredient used in commercial formulations used as adjuvant is toxic. More recently, Samsel and Sanoff (2013) claim that “glyphosate enhances the damaging effects of other foodborne chemical residues and environmental toxins.”

[3] HT crops also simplify the management of pesticide application (Carpenter and Gianessi, 1999). There is a greater window over which the herbicides can be applied (glyphosate can be effective on older plants). This makes it much easier to manage weather-related delays to the herbicide application schedule. Use of glyphosate also may reduce the need for aerial applications that are sometimes needed when it is too wet to enter the field.

GE-Crop Adoption and Conservation Tillage

(From Fernandez-Cornejo (2014a): 26-28)

Conservation tillage (including no-till, ridge-till, and mulch-till) is known to provide environmental benefits (USDA ERS/NRCS 1998; NRC 2010). By leaving substantial amounts of crop residue (at least 30 percent) covering the soil surface after planting, conservation tillage reduces soil erosion by wind and water, increases water retention, and reduces soil degradation and water/chemical runoff. In addition, conservation tillage reduces the carbon footprint of agriculture.

Adopters of HT crops practice conservation tillage more than growers of conventional varieties. Since the 1980s, the adoption of conservation tillage practices by U.S. farmers has been facilitated by the availability of post-emergent herbicides that can be applied over a crop during the growing season. Post-emergent herbicides are especially beneficial in no-till production systems because these herbicides control weeds without tilling the soil. HT crops have helped spread no-till farming further since they often allow a more effective system than just using other post-emergent herbicides (Fernandez-Cornejo and Caswell 2006). According to USDA survey data, 60 percent of HT soybean planted acres used conservation tillage practices in 1997 versus 40 percent of conventional soybean acres (Fernandez-Cornejo and Caswell 2006). By 2006, approximately 86 percent of HT soybean planted acres were under conservation tillage compared to only 36 percent of conventional soybean acres. Differences in the use of no-till specifically are just as pronounced. While approximately 45 percent of HT soybean acres were cultivated using no-till technologies in 2006, only 5 percent of the acres planted with conventional seeds were cultivated using no-till techniques.[4] Cotton and corn data exhibit similar though less pronounced patterns. Thirty-two percent of HT cotton acres were planted using conservation tillage in 2007, compared to 17 percent of conventional cotton acres. Thirty-three percent of HT corn acres were planted using no-till in 2005, versus 19 percent of conventional corn acres.

These trends suggest that HT crop adoption may encourage soil conservation practices. In addition, a review of several econometric studies point to a two-way causal relationship between the adoption of HT crops and conservation tillage (NRC 2010). This implies that the adoption of herbicide-tolerant crops indirectly benefits the environment.

Insect Resistance to Bt Crops

(From Fernandez-Cornejo (2014): 29-31)

Pesticide resistance evolution occurs when pesticide use favors the survival of pests naturally resistant to the pesticide. Over time, these resistant pests become predominant in the pest population. Developers of Bt crops and other researchers recognized early on that insect resistance to Bt toxins could develop. Measures to delay the onset of such resistance (such as refuges) were taken and, so far, the emergence of insect resistance to Bt crops has been low and of "little economic

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[4] No-till systems are often considered the most effective of all conservation tillage systems. They leave 100 percent of crop residues on the soil surface and the soil is undisturbed from harvest to planting, resulting in the highest percentage of surface being covered by crop residues, minimizing soil loss and water runoff (Janssen and Hill, 1994).

and agronomic significance" (NRC 2010), but there are some indications that insect resistance is developing to some Bt traits in some areas.[5]

Prior to the availability of Bt crops, entomologists and other scientists successfully argued that mandatory refuge requirements—planting sufficient acres of the non-Bt crop near the Bt crop—were needed to reduce the rate at which targeted insect pests evolved resistance. Such refuges slow the rate at which Bt resistance evolves by allowing target insects that are susceptible to the Bt toxin to survive and reproduce. To be effective, the refuge must be positioned appropriately and be large enough to ensure that insects that survive on the Bt acres mate with insects that survive on the non-Bt acres. Such interbreeding increases the chances that their progeny are susceptible, having inherited Bt resistance as a recessive trait.[6]

The U.S. Environmental Protection Agency (EPA) instituted mandatory refuge requirements as a condition of the registration of Bt corn and Bt cotton varieties for commercial use in the United States. This was the first time regulations were used to manage resistance to a pest control technology. Bt crop growers were required to sign a contract with their technology provider to comply with minimum refuge requirements, and technology providers were required to monitor and enforce grower compliance. An analysis of more than a decade of monitoring data suggests that the minimum refuge requirement, as well as natural refuges that also serve as hosts for target insect pests, has helped delay the evolution of Bt resistance (Tabashnik et al. 2008).

Refuge requirements are reduced for multiple-toxin Bt cotton varieties in some areas. EPA has eliminated the minimum refuge requirement for certain Bt cotton varieties that express multiple toxins in areas that appear to have sufficient unstructured refuge, but not for Bt corn varieties that express multiple toxins. The latter are less toxic to an important target pest known as the western corn rootworm, which might inherit Bt resistance as a partially dominant trait. Recently, western corn rootworm larvae were collected from Iowa Bt cornfields that showed evidence of root damage, and laboratory assays later confirmed that their progeny were less susceptible to Bt toxins (Gassmann et al. 2011). This has raised concerns about regulatory compliance and a continued need for minimum refuge requirements for Bt corn growers.

[5] There is some indication of emergence of Bt-resistant corn rootworm in some parts of the Corn Belt http://www.bloomberg.com/news/2012-09-04/-mounting-evidence-of-bug-resistant-corn-seen-by-epa.html. http://bulletin.ipm.illinois.edu/article.php?id=1704. There is also anecdotal evidence that resistance is a contributing factor to increasing corn insecticide sales in 2012 and 2013 (I. Berry; *WSJ*, May 21, 2013). Tabashnik et al. (2013) recently analyzed 77 studies carried out in 5 continents from 1996 to 2012. They find that "although most pest populations remained susceptible, reduced efficacy of Bt crops caused by field-evolved resistance has been reported now for some populations of 5 of 13 major pest species examined, compared with resistant populations of only one pest species in 2005." They conclude that "the increase in documented cases of resistance likely reflects increases in the area planted to Bt crops, the cumulative duration of pest exposure to Bt crops, the number of pest populations exposed and improved monitoring efforts." They also conclude that while "regulations in the United States and elsewhere mandate refuges of non-Bt host plants for some Bt crops, farmer compliance is not uniformly high and the required refuge percentages may not always be large enough to achieve the desired delays in evolution of resistance. Both in theory and practice, using Bt crops in combination with other tactics as part of integrated pest management may be especially effective for delaying pest resistance."

[6] A dominant trait will be expressed in progeny if at least one of the parents has the gene for that trait. A recessive trait will be inherited if both parents have the gene for that trait. (Hedrick, 2000).

Emergence of glyphosate-resistant weeds

(From Livingston et al. (2015): 1-3)

Glyphosate was first marketed in 1974 under the name Roundup. Its use increased rapidly with the commercial introduction of glyphosate-tolerant (GT) corn, soybeans, and cotton in 1996 and patent expiration in 2000, which led to the availability of relatively inexpensive generic equivalents. Glyphosate is reported to be less toxic and less persistent in the environment relative to the herbicides that it replaced (Malik et al., 1989, Duke and Powles 2008; NRC 2010). The National Research Council (2010) reported that glyphosate is biodegraded by soil bacteria and it has a very low toxicity to mammals, birds, and fish.[7] As a result, glyphosate has been the most widely used pesticide in the United States since 2001 (Fernandez-Cornejo et al. 2014; Grube et al. 2011; Osteen and Fernandez-Cornejo 2013). U.S. crop growers now plant 93 percent of their soybean acres and 85 percent of their corn acres to genetically engineered (GE) herbicide-tolerant (HT) varieties (figure 3-14).[8] The emergence of the HT varieties led corn and soybean growers to increase their use of glyphosate over time and reduce their use of all other herbicides. During 1996-2003, herbicide use in corn and soybean production declined from about 293 million pounds of active ingredient to around 247 million pounds. Since 2003, herbicide use on acreage planted with these two crops has increased to almost 353 million pounds of active ingredient in 2013, with glyphosate accounting for over 57 percent of the total.[9]

However, glyphosate is becoming less effective at controlling some weeds. The International Survey of Herbicide Resistant Weeds identified 14 glyphosate-resistant (GR) weed species currently affecting U.S. crop-production areas (Heap 2014).[10] GR weeds can increase weed control costs and decrease crop yields (Shaw et al. 2011; Mueller et al. 2005; Scott and VanGessel 2006; Culpepper et al. 2008; Culpepper and Kichler 2009; Webster and Sosnoskie 2010). Recent surveys of crop growers in 31 States suggest that acreage with GR weeds is increasing (Fraser 2013). Because no new major herbicide active ingredients have become commercially available in the last 20 years, and because few new herbicides are expected to be available anytime soon (Harker et al. 2012), plant scientists have suggested that slowing the spread of GR weeds is a serious challenge facing U.S. crop growers (NRC 2010).

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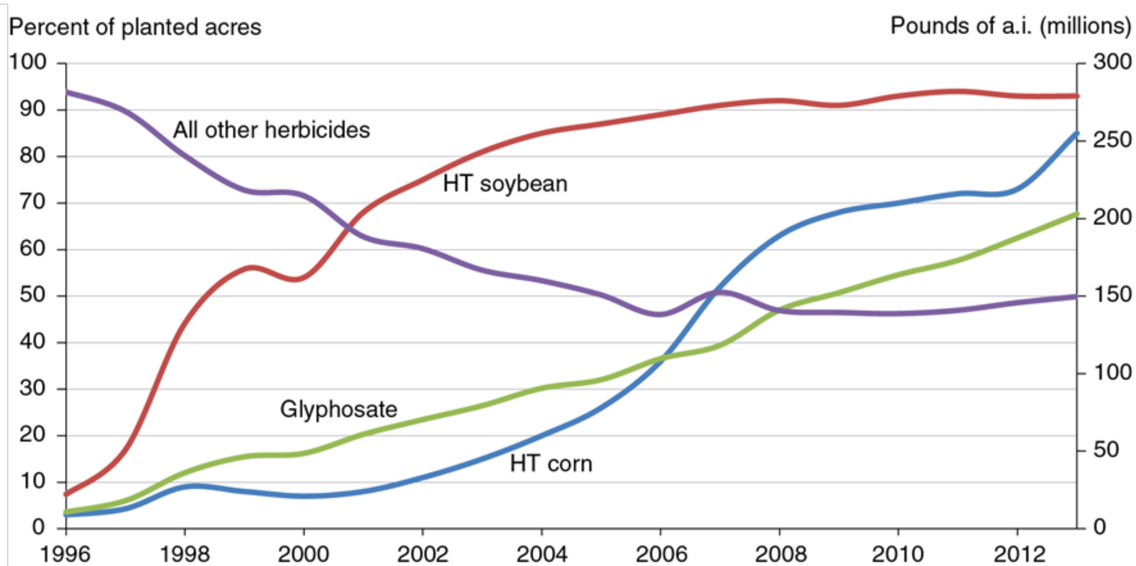
[7] Regarding toxicity to humans and based on risk assessments, the U.S. Environmental Protection Agency (EPA) concluded that glyphosate had minimal human dietary exposure and risk, and that exposure to workers and other applicators would not pose undue risk, because of low acute toxicity. However, EPA recommended personal protective equipment for skin and eye irritation, and a 12-hour re-entry interval on treated agricultural areas to mitigate potential risks (U.S. Environmental Protection Agency, 1993). Glyphosate is currently under a standard registration review by EPA, the outcome of which is expected in 2015. (http://www.epa.gov/oppsrrd1/registration_review/reg_review_status.htm). More recently, on March 20, 2015, the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) issued a summary of the final evaluations of 5 pesticides including glyphosate that classifies glyphosate as “Probably Carcinogenic to Humans” http://www.iarc.fr/en/media-centre/iarcnews/pdf/MonographVolume112.pdf

[8] Genetically engineered corn and soybean varieties that tolerate the herbicide glufosinate became commercially available after 1996, but the majority of herbicide-tolerant (HT) corn and soybean varieties planted in the United States have been glyphosate-tolerant (GT) varieties

[9] The increase in herbicide use in corn and soybean production is partially due to the increase in acres planted to these two crops—from 152 million acres in 2003 to 175 million acres in 2013

[10] The current U.S. count is 14 according to the International Survey of Herbicide Resistant Weeds. http://weedscience.com/summary/MOA.aspx (accessed on January 5, 2015).

Figure 3-14. Adoption of genetically engineered herbicide-tolerant (HT) corn and soybeans and pounds of herbicide active ingredients (a.i.) applied to those crops, 1996-2013



Source: USDA, Economic Research Service estimates. Data for GE adoption from Fernandez-Cornejo, J. Adoption of Genetically Engineered Crops in the U.S., Data Product, http://www.ers.usda.gov/Data/BiotechCrops/ July 2014.
Data for herbicide use estimates come from the Agricultural Resource Management Survey (ARMS) Phase II and from USDA (2014). Regressions were used to interpolate herbicide missing data.

Exclusive reliance on one herbicide as the sole control tactic over the majority of the corn, cotton, and soybean acres in the Midwest and South is believed to be the main factor underlying the growing resistance of weeds to glyphosate. The Weed Science Society of America (WSSA) recently described an herbicide resistance management strategy that can reduce the spread of weeds resistant to a single herbicide (Norsworthy et al. 2012). The strategy involves understanding the biology of the weeds that are present and using diverse chemical, cultural, and mechanical methods to control weeds and reduce the production and dissemination of weed seeds. Using multiple herbicides with different modes of action (MOA), rotating use of different herbicide MOAs over time, and adopting several other resistance management practices (RMPs) can reduce the spread of weeds resistant to a single herbicide.[11]

Perhaps, because of a lack of information and economic incentives, many crop growers only use *some* RMPs, and they use them *after resistance develops*, in response to resistance, instead of using them to delay the onset and spread of herbicide resistance. Many crop growers reportedly believe that there is no need to use some RMPs, holding to a view that new herbicides will be available in time to control weeds resistant to currently available herbicides (Norsworthy et al. 2012). Some RMPs also increase current production costs, whereas the future benefits of delaying the spread of weed resistance by using RMPs are uncertain (Frisvold et al. 2009).

[11] Herbicides control weeds by disrupting one or more vital metabolic process, like photosynthesis or protein synthesis. Herbicides that kill weeds by disrupting different metabolic processes are said to have different modes (or mechanisms) of action, or MOA

Moreover, because weed seeds can disperse between fields by wind (Dauer et al. 2009), water, animals, and humans, including movement on farm equipment (Ross and Lembi 2009), the effectiveness of RMPs in delaying resistance on one farm can depend on their use on neighboring farms. As a result, the susceptibility of weeds to glyphosate is an example of what economists refer to as a "common pool resource," which is especially prone to overuse (Ostrom et al. 1999).[12] For mobile pests like insects and weeds, market-based economic incentives might be insufficient to ensure that resistance is managed in an economically optimal manner (Miranowski and Carlson 1986; Livingston 2013).

<u>Glyphosate-resistance management strategies</u>
(From Livingston et al. (2015): 3)
Stakeholders are responding to the spread of GR weeds in a number of ways. Plant scientists focus on information campaigns that raise awareness of resistance and communicate the benefits of using RMPs (Duke and Powles 2009; Norsworthy et al. 2012; Price et al. 2011; Vencill et al. 2012). The seed industry, government agencies, and other organizations are helping to finance these efforts (Farm Industry News 2014; Boerboom and Owen 2006). The seed industry is in the process of registering new GE crop varieties that can tolerate herbicides with a range of MOAs. GE corn varieties that tolerate glyphosate and glufosinate are currently available, and USDA has been reviewing industry proposals to deregulate new GE corn and soybean varieties that tolerate glyphosate and 2,4-D (now deregulated) or glyphosate and dicamba (Johnson et al. 2012; USDA APHIS 2014).[13] Some herbicide registrants have been offering incentives (such as per-acre payments) to purchase specific herbicide products with different MOAs than glyphosate's, such as acetochlor, atrazine, or other chemicals, to use with glyphosate on corn, cotton, or soybeans, depending on the type and brand of seed used.

USDA's Natural Resources Conservation Service (NRCS) is promoting the use of RMPs under its Integrated Pest Management Herbicide Resistance Weed Conservation Plan. The agency provides financial assistance for developing conservation activity plans under the Environmental Quality Incentives Program. The plans provide guidelines to delay herbicide resistance and meet soil, water, and air quality objectives.

<u>Weed-management practices in corn and soybean production, 1996-2012</u>
(From Livingston et al. (2015): 6-10)
To identify ways to promote the use of RMPs in corn and soybean production, it is important to understand how growers have managed weeds in those crops since the commercial introduction of

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[12] Some economists consider pest susceptibility to pesticides a common pool resource. When a pest moves from farm to farm, the pest control decisions made by any given farmer will affect the pest susceptibility (and returns) accruing to that farmer as well as those accruing to nearby farmers, but to a lesser extent. However, the effects of any one farmer's control decisions on the (susceptibility of) regional pest populations are practically negligible and the benefits and costs associated with those effects are not borne by any given farmer. Thus, those effects might not be accounted for in the farmer's control decision (Feder and Regev, 1975; Fernandez-Cornejo et al., 2014a). Pollen and seeds of many different weed species can disperse between farms in the air and in conjunction with the movement of animals and farm machinery (Fernandez-Cornejo et al., 2014a).

[13] Concerns have been raised that the longrun sustainability of these new GE varieties might be undermined by the lack of information and economic incentives that are currently keeping crop growers from using RMPs until resistance occurs (Union of Concerned Scientists, 2013).

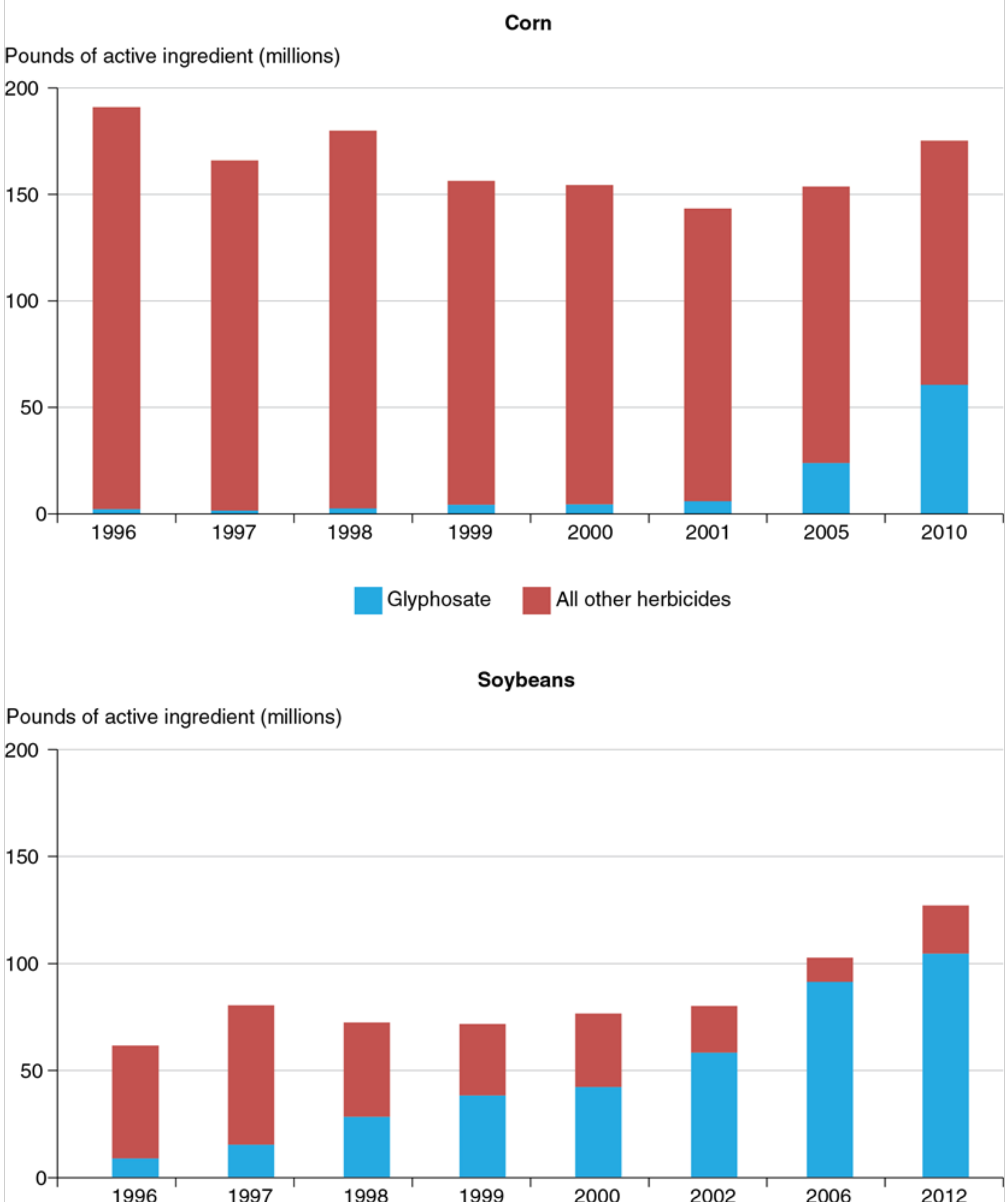
GT varieties in 1996. We examined ARMS data collected from corn and soybean growers during 1996-2012 to identify relevant trends and differences in corn and soybean management practices and explanations for the trends and differences.

Since using glyphosate by itself repeatedly over time is the most important factor underlying the evolution of glyphosate resistance (Norsworthy et al. 2012), ARMS data suggest that herbicide-use practices in soybean production promoted the spread of GR weeds to a greater extent than herbicide-use practices in corn production. HT varieties (mostly GT varieties) were planted on more soybean than corn acres (see figure 3-14); much more glyphosate (expressed in pounds of active ingredient) was applied to soybean than to corn fields (figure 3-15); and glyphosate was used by itself on far more soybean than corn acres (figure 3-16). At the same time, the total quantity of herbicide active ingredient applied was much greater on corn than soybean acreage, and herbicides other than glyphosate accounted for the majority of the herbicides applied to corn. In addition, tillage, which controls weeds without encouraging herbicide resistance, was used more in corn than in soybean production, whereas no-till production systems were used more for soybeans than for corn (Horowitz et al. 2010).

Weed management in corn fields involves not only glyphosate, but also other inexpensive herbicides, such as atrazine. In contrast, weed management in soybean fields is largely managed with glyphosate alone, because the next best alternative herbicides to control soybean weeds, especially broadleaf weeds, are more expensive, less effective, and can injure soybean plants (NRC 2010). These facts help explain why GT soybean adoption was more rapid than GT corn adoption, why much more glyphosate was used in soybean than in corn production, and why far more soybean than corn acres received glyphosate by itself during 1996-2012.

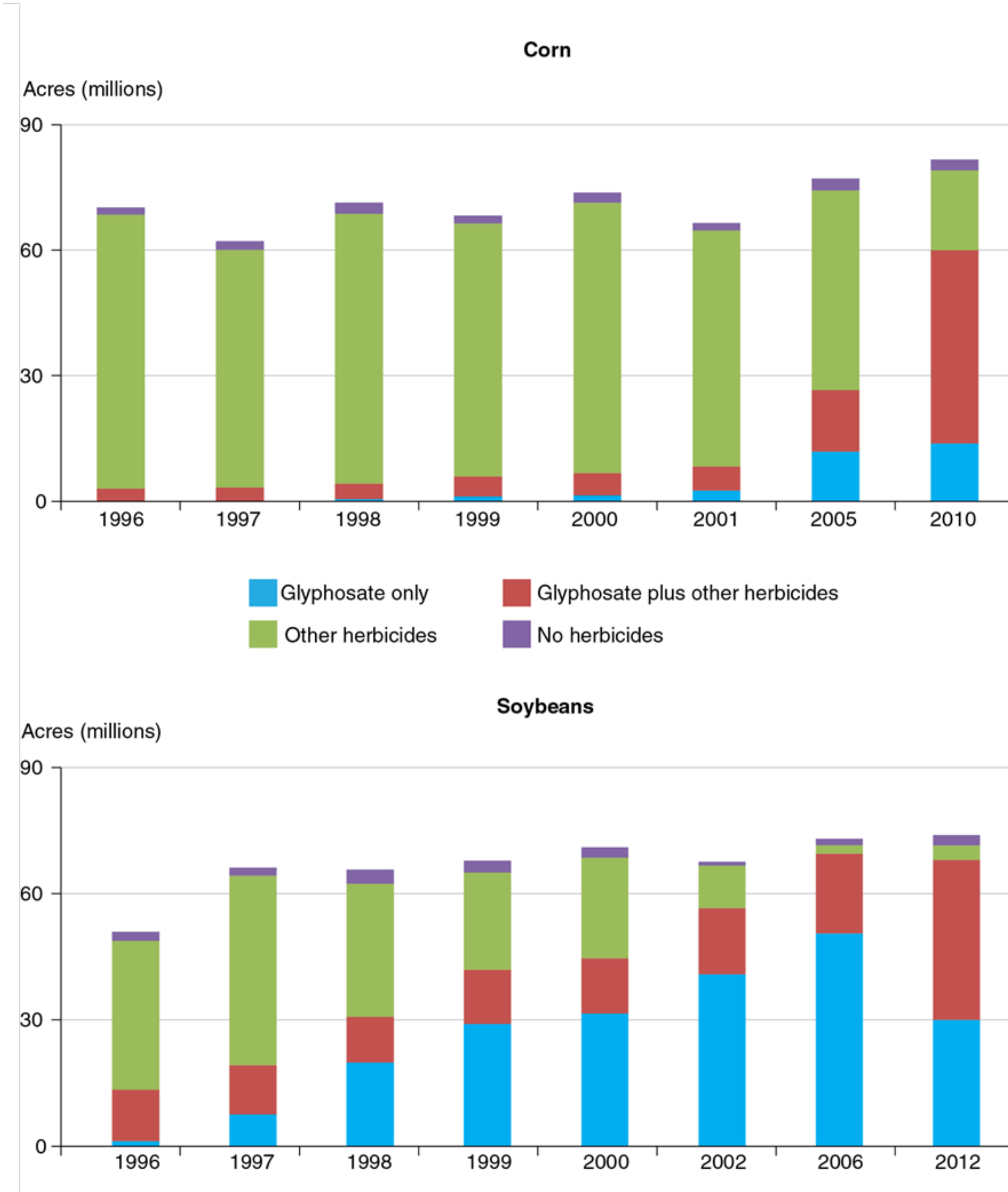
Herbicide use on soybeans in surveyed States increased from about 60 million pounds of active ingredient (a.i.) in 1996 to 103 million pounds in 2006 (see figure 3-15). Glyphosate's share increased from 15 percent of the herbicide active ingredient applied in 1996 to 55 percent in 2000; by 2006, its share had increased to 89 percent. The percentage of soybean acres (in surveyed States) treated with glyphosate, by itself or in combination with other herbicides, increased from about 25 percent in 1996 to over 60 percent in 2000, and to about 95 percent in 2006 (figure 3-16). Moreover, soybean acres treated with glyphosate as the sole herbicide increased from only 9 percent in 1996 to 73 percent in 2006.

Figure 3-15 Herbicide quantity applied to corn and soybean, surveyed States, 1996-2012



Source: USDA, Economic Research Service estimates using data from the Agricultural Resource Management Survey (ARMS) Phase II.

Figure 3-16 Corn and soybean acreage that received different groups of herbicides, surveyed States, 1996-2012



Source: USDA, Economic Research Service using data from the Agricultural Resource Management Survey (ARMS) Phase II.

Because of the presence of GR weeds in soybean fields, discussed later, both of these trends changed between 2006 and 2012. The amount of other herbicides (with different MOAs) applied to soybeans almost doubled; from 11.4 million pounds in 2006 to 22.5 million pounds in 2012 (see figure 3-15).[14] As a result, glyphosate accounted for 82 percent of total herbicide active ingredient applied to soybeans in 2012, down from 89 percent. The soybean acreage that received glyphosate by itself also declined, from 51 million in 2006 to 30 million in 2012 (a decline from 73 percent to 44 percent of glyphosate-treated acreage), because the number of soybean acres that received glyphosate and at least one different herbicide MOA more than doubled, from 19 million acres in 2006 to over 38 million acres in 2012 (an increase from 27 percent to 56 percent of glyphosate-treated acreage) (see figure 3-16).

Much more total herbicide was applied in corn than in soybean production, and herbicides other than glyphosate accounted for the majority of herbicides used on corn fields. Herbicide use on corn in surveyed States declined from 191 million pounds of active ingredient in 1996 to 143 million pounds in 2001, but then increased to 175 million pounds in 2010 (see figure 3-15). Glyphosate accounted for only 1 percent of herbicide use in 1996, but as HT corn varieties were planted to more acres, glyphosate use grew to 35 percent of total herbicides applied in 2010.

The percentage of glyphosate-treated corn acreage rose steadily from 4 percent of planted acres in 1996 to 35 percent in 2005 to 73 percent in 2010. So, the majority of surveyed corn acreage received no glyphosate from 1996 (96 percent) to 2005 (65 percent). The percentage of all glyphosate-treated corn acres that received only glyphosate increased from about 1 percent in 1996 to 21 percent in 2000 to 44 percent in 2005, but declined to only 23 percent in 2010, perhaps due to the presence of GR weeds (see figure 3-16).[15] So, the majority of glyphosate-treated corn acres received at least one additional herbicide MOA throughout this period, with the lowest percentage occurring in 2005.

Resistance Management Practices

Corn and soybean growers used a variety of RMPs during 1996-2012. (Table 3-2 shows the use of a selection of those practices on corn and soybean acres based on ARMS data.) The majority of corn and soybean acres were scouted for weeds, exceeding 80 percent in most survey years, and this practice was used on an increasing percentage of soybean and corn acres, although corn acres scouted did not increase as much at the end of the period. Crops were rotated on over 75 percent of soybean acres and a smaller percentage of corn acres, with little change in either crop during this period.

Tillage was used on over half of corn and soybean acres, with a greater percentage of corn than soybean acres being tilled.[16] Except for soybeans in 2012, there was a slight downward trend in tilled acres for both crops, perhaps in response to GR weed infestations. As Price et al. (2011) observe, many acres under conservation tillage "are at risk of being converted to higher-intensity

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[14] Weed scientists classify glyphosate as the only inhibitor of 5-enolpyruvyl-shikimate-3-phosphate (EPSP) synthase, a unique mode of action (Mallory-Smith and Retzinger, 2003). All other corn and soybean herbicides considered in this report have a different mode of action than glyphosate

[15] Over 1.4 million corn acres in surveyed States received glyphosate by itself in 2000, increasing to 13.8 million acres in 2010. Over 5.3 million corn acres received glyphosate plus at least one different herbicide MOA in 2000; this increased to 46.2 million acres by 2010

[16] In the ARMS Phase II questionnaire, farmers were asked to indicate if they "plow down crop residue (using conventional tillage) with the purpose of reducing the spread of pests in the field." For this reason, answers to these questions may be somewhat different from usual tillage questions based on actual tillage operations.

tillage systems due to the inability to control” glyphosate-resistant weeds. They add that “the decline of conservation tillage is inevitable without the development and rapid adoption of integrated, effective weed control strategies.” Moreover, if conservation tillage declines, its benefits (in reducing soil erosion and improving soil quality and water conservation) will also be at risk.

Table 3-2

Use of resistance management practices on corn and soybeans, 1996-2012

Year	Used herbicide other than glyphosate	Used tillage	Scouted for weeds	Rotated crops	Adjusted planting dates	Adjusted plant density	Rotated pesticides	Mowed field edges	Cultivated for weed control
				Planted acres (percent)					
Corn									
1996	98	82	81	71	7	5	32	34	55
1997	97	83	80	75	4	5	32	34	55
1998	95	87	86	74	3	5	46	34	42
1999	96	85	86	76	4	5	43	40	48
2000	95	83	83	74	7	7	45	40	38
2001	94	84	84	77	3	4	40	31	37
2005	81	77	89	73	10	11	24	43	15
2010	80	74	88	69	14	13	27	44	15
Soybean									
1996	93	66	79	81	8	11	28	31	29
1997	86	71	83	80	3	11	32	31	28
1998	65	71	85	84	5	11	43	31	26
1999	53	69	87	79	3	17	36	38	22
2000	52	69	85	77	5	17	34	41	17
2002	38	66	85	84	4	18	22	37	19
2006	29	56	90	85	13	19	13	45	8
2012	56	59	94	82	15	18	24	43	8

Note: In the ARMS Phase II questionnaire, growers were asked to indicate if they used each resistance management practice “with the purpose of reducing the spread of pests in the field.”
Source: USDA, Economic Research Service using data from the Agricultural Resource Management Survey (ARMS) Phase II.

The percentage of planted acres that received herbicides with MOAs other than glyphosate’s declined at least initially, for both crops; however, the decline was much more dramatic for soybeans than for corn. The share of soybean acres receiving herbicides with MOAs other than glyphosate’s declined steadily from 93 percent in 1996 to 29 percent in 2006, before increasing to 56 percent in 2012, perhaps due to the rising presence of GR weeds. The share of corn acres that received at least one herbicide MOA other than glyphosate’s declined from 98 percent in 1996 to 80 percent in 2010.

Other RMPs were used on less than 50 percent of corn and soybean acres during this period. A greater percentage of corn than soybean acres was cultivated for weed control, but acres receiving that practice declined steadily for both crops. For both crops, the practice of rotating or alternating pesticides to delay pesticide resistance increased during the first half of the period, then declined during the latter half, with the exception of the last years, perhaps in response to the presence of more GR weeds. Mowing field edges and roadways to prevent pest introductions increased after 2000, as did two other RMPs, previously used sparingly: adjustments to planting dates (to avoid weeds) and plant density or row spacing (to crowd out weeds). Finally, some practices (not included in table 1) showing very small differences in their use across time and between corn and soybean acres were "planting a cover crop in the fall," on 0.9 percent of corn and 0.5 percent of soybean acres; "keeping written records of weeds observed," on 21 percent of corn and 21 percent of soybean acres; and "cleaning equipment between fields," on 29 percent of corn and 31 percent of soybean acres.

3.10 Climate change

Climate change is beginning to affect the state of biodiversity for food and agriculture, with larger impacts expected over time if current projections of temperature rise are realized. An assessment of the current state of biodiversity for food and agriculture would not be complete without an accounting of current and anticipated changes in biodiversity for food and agriculture due to climate change.

A 2012 report released by the U.S. Department of Agriculture investigates the direct and indirect effects of climate change on U.S. agriculture, including "effects arising from changes in the severity of pest pressures, availability of pollination services, and performance of other ecosystem services that affect agricultural productivity" (pg 2, Walthall et al. 2012). The report focuses on five areas of impact on associated biodiversity for food and agriculture: weeds, invasive species, pathogens, soil quality, and pollinators. The material below is excerpted from the USDA report (Climate Change and Agriculture in the United States: Effects and Adaptation (Walthall et al. 2012)). Page numbers for the source material is provided at the top of each section. Skipped material is denoted by "+ + +".

Climate Change Effects on Weeds, Insect Pests and Pathogens

(From Walthall et al. 2012: 39-52)

Changes in temperature and precipitation patterns, coupled with increasing atmospheric CO_2, create new conditions that change weed-infestation intensity, insect population levels, the incidence of pathogens, and the geographic distribution of many of these pests. Such changes on non-crop species found in agroecosystems are indirect effects of climate change. For agriculture, such effects can alter production yields and quality, and may necessitate changes to management practices. These indirect effects may also increase farming costs, as additional inputs may be required to manage the influence of weeds, invasive species, insects, and other pests. Weeds cause the highest crop losses globally (34 percent), with insect pests and pathogens showing losses of 18 percent and 16 percent, respectively (Oerke 2006). In the following sections, some of the indirect effects of climate change on weeds, pests, and pathogens and their respective effects on U.S. agriculture will be sketched out.

Weeds and invasive plants

Cropland agriculture, in its simplest arrangement, can be characterized as a managed plant community that is composed of a desired plant species (the crop) and a set of undesired plant species (weeds). Agronomic weeds reduce food production through competition for light, nutrients, and water, and by reducing production quality, increasing harvest interference, and acting as hosts for other pest vectors. By altering the environment (e.g., temperature) or increasing a resource (e.g.,

CO_2), we change not only the growth of an individual, but also the interactions among species, and the growth patterns of the entire plant community.

Weed scientists have long recognized that temperature controls weed species success (Woodward and Williams 1987). Thus, warming will affect the dissemination of weeds with subsequent effects on their growth, reproduction, and distribution. Many of the most troublesome weeds in agriculture – both warm-season (C3) and cool-season (C4) species – are confined to tropical or subtropical areas (Holm et al. 1997); the lower temperature extremes that occur at higher latitudes are inhospitable to many weeds. High-latitude temperature limits of tropical species are set by accumulated degree days (Patterson et al. 1999), while low-latitude limits are determined, in part, by competitive ability to survive at lower temperatures (Woodward 1988). However, because many weeds associated with warm season crops originate in tropical or warm temperature areas, northward expansion of these weeds may accelerate with warming (Patterson 1993; Rahman and Wardle 1990).

For maize and soybean crops within the United States, there is a clear latitudinal distinction between the Great Lakes (Michigan, Minnesota, Wisconsin) and Gulf States (Alabama, Louisiana, Mississippi) with respect to weed limitations (Bunce and Ziska 2000). The greater soybean and corn losses in the southern Gulf States are associated with a number of very aggressive weed species found in tropical or subtropical areas (e.g., prickly sida and Johnson grass). Warmer temperatures, in particular an increase in the number of frost-free days, may allow a northward expansion of these aggressive weeds into other areas of the Midwest, with subsequent effects on maize and soybean production. An analysis of such changes, using a "damage niche" hypothesis, and a "business as usual" climate scenario (IPCC 2007) showed significant changes in the range of two weed species affecting corn in the northern and southern United States (velvetleaf and Johnson grass, C3 and C4 weeds, respectively) (McDonald et al. 2009). Based on these initial evaluations, velvetleaf, a cold-tolerant annual weed, is likely to become less problematic in the Corn Belt; whereas Johnson grass, a warm-season perennial, may become more common, advancing northward by 200 to 600 km by midcentury.

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Invasive weeds compete with desired plants in rangelands, pastures and other perennial agricultural systems in the United States, reducing both food production and biological diversity (DiTomaso 2000). A key difference between agronomic weeds and invasive plants, with respect to global change, is that global changes that influence plant resources (water, N, light, C) influence invasive weeds particularly strongly (Bradley et al. 2010).

Both warming and precipitation change can alter plant resources and invasion. Experimental warming has been found to favor invasion in relatively wet European grassland (Verlinden and Nijs 2010), but to have little effect on, or to inhibit invasive species in drier California and New Zealand grasslands, perhaps because it increases evapotranspiration and therefore water limitation (Williams et al. 2007; Verlinden and Nijs 2010; Dukes et al. 2011). As with agronomic weeds, warming may be most likely to favor C4 invaders competing with C3 species (Bijoor et al. 2008) and inhibit C3 invaders competing with C4 species (Williams et al. 2007). The few experiments examining how changing precipitation might influence invasion suggest that effects depend on seasonality. Increases in winter precipitation favored invasive species in mixed-grass prairie (Blumenthal et al. 2008), while increases in spring precipitation favored invasive species in California and Utah grasslands (Miller et al. 2006; Thomsen and D'Antonio 2007). Across studies and ecosystems, invasive species tend to use more water than natives (Cavaleri and Sack 2010), suggesting that invasive species may often be favored by increased water availability during their growing season (Bradley 2009). Therefore, the large sections of the United States that are expected to receive higher precipitation may need to engage more actively in invasive weed management.

In addition to altering the success of invasive species within plant communities, changes in climate are also likely to alter the distributions of those species (McDonald et al. 2009; Watt et al. 2009; Ibanez et al. 2009; Bradley 2009; Bradley et al. 2010b; Jarnevich and Reynolds 2011.) Biogeographical modeling, which uses current spatial distribution to identify suitable habitat under future climate conditions, suggests that rising temperatures and altered precipitation may not consistently increase invasive species' ranges (Bradley et al. 2010a). For some species, projected changes in climate primarily cause an expansion of invasion risk (e.g., Jarnevich and Stohlgren 2009; McDonald et al. 2009; Bradley et al. 2010b), particularly near the cooler margins of their range (poleward and upward in elevation). For other species, climate change may reduce invasion risk in portions of the invaded range (e.g., Parker-Allie et al. 2007; Beaumont et al. 2009; Bradley 2009). For example, a model of spotted knapweed risk suggests that the species' potential range will be substantially reduced with climate change, while cheatgrass's potential range shifts, expanding into currently wetter areas and contracting from currently drier areas.

Extreme climatic events such as drought, flooding, and strong storms, which are predicted to become more frequent with climate change, can also influence weed invasion (Jimenez et al. 2011; Diez et al. 2012). While decreasing precipitation might be expected to inhibit invasion, severe or extended droughts can act as disturbances, decreasing biotic resistance from native species, and providing opportunities for invasive species once precipitation returns. For example, in Arizona rangeland, severe drought in 2004 and 2005 led to the death of many native shrubs and grasses, followed by rapid invasion and dominance by Lehmann lovegrass (*Eragrostis lehmanniana*) (Scott et al. 2010). Similarly, hurricanes in Florida and Louisiana have damaged forests and increased cover of invasive vines (Horvitz et al. 1998; Brown et al. 2011).

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The combined effects of multiple global changes on invasion are difficult to predict, but could have serious consequences for perennial agricultural systems. For example, in mixed-grass prairie, the combination of increased winter precipitation and simulated N deposition increased invasion much more than the sum of the two individual changes (Blumenthal et al. 2008). In contrast, while elevated CO2 and N increased yellow starthistle (*Centaurea solstitialis*) biomass 6-fold and 3-fold, respectively, in California grassland, their combined effects were additive (Dukes et al. 2011). Multiple global changes may also influence invasion through interactions with fire. Both elevated CO2 and severe droughts can favor fire-promoting invasive grasses in western U.S. rangelands (Smith et al. 2000; Brooks 2003; Ziska et al. 2005; Scott et al. 2010; Mazzola et al. 2011). At the same time, warmer temperatures and earlier cessation of cool-season precipitation are expected to increase the number and intensity of fires (Abatzoglou and Kolden 2011). The likely result is further transformation of diverse native rangelands into near-monocultures of invasive grasses (Bradley 2009; Abatzoglou and Kolden 2011).

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Insect Pests

The geographic ranges of insect pests are limited by the presence of the plants upon which they feed, and the ability of the insects to survive winter temperatures. However, through local dispersal and long-distance migration, some insects may reinvade colder regions annually. Spring emergence is generally defined by temperature, whereas winter dormancy is cued by photoperiod or a combination of photoperiod and temperature. Insects are capable of withstanding all but the most extreme precipitation events, thus rainfall affects growth and survival principally through increased cloud cover, which can reduce activity, and changes in the nutritional quality of the plants upon which insects feed. Insects, especially small ones and those with aquatic life stages, will desiccate and die without ready access to water. Humidity influences the prevalence of insect diseases, as well as plant diseases that insects carry. Although food quality is important to their growth, survival of many insects is dependent upon predation in natural ecosystems with chemical, biological, and microbial controls used to suppress pests, and sometimes their predators, below their natural level in agroecosystems.

Generally, increasing air temperature is beneficial to insect pests. As long as upper critical limits are not exceeded, rising temperatures accelerate every aspect of an insect's life cycle, and warmer winters reduce winter mortality. Although increased summer temperatures also favor growth of insect populations, extension of the growing season has a proportionately greater effect on the damage insects inflict on their host plants (Bradshaw and Holzapfel 2010). Moreover, pests' greater nutrient demands in early spring and autumn coincide with the planting and fruiting stages –stages that are particularly vulnerable for many crops and critically important for successful production.

Increasing air temperature has resulted in reduced cold stress without substantial increase in heat stress (Bradshaw and Holzapfel 2006), although decreased soil temperatures in areas with reduced frequency of snow cover can result in greater winter insect mortality (Bale and Hayward 2010) because arousal from winter dormancy is generally dependent on accumulated temperature (growing-degree days). Research shows examples of insect phenology advancing faster than previously experienced within a season (Gordo and Sanz 2006; Harrington et al. 2007; Gregory et al. 2009; Bale and Hayward 2010). Some insects spawning multiple generations per season have responded to longer growing seasons by producing more generations per year (Tobin et al. 2008; Altermatt 2010), which, in addition to adding more insects to the environment, can lead to pests developing greater resistance to insecticides (May and Dobson 1986).

The overall positive influence of increasing air temperature on expansion of insect geographical ranges is well documented in natural systems, although some insects' ranges have shifted and others have contracted (Walther et al. 2002; Parmesan and Yohe 2003; Parmesan 2006; Walther 2010). Earlier migration and maturation result in successful colonization of habitats that were formerly outside an insect population's range (Bale and Hayward 2010). However, as is the case for crops, insects have optimal temperatures under which they thrive, so not all insect populations will increase with increasing temperature.

Increased winter survival in newly colonized habitats also contributes to successful expansion (Crozier 2004). Less work has been done in agroecosystems, but Diffenbaugh et al. (2008) projected range expansion of the corn earworm, European corn borer, and the Northern and Western corn rootworms in the United States based upon tolerance to minimum absolute temperature, number of hours below 10°C, and the required growing-degree days in the first half of the year. Models project that geographic ranges will expand for all four species by 2100, indicating that insects from diverse lifestyles may be affected similarly by recent and future temperature changes (Diffenbaugh et al. 2008).

Projected increases of extreme precipitation events could make pest population outbreaks and crashes more common (Hawkins and Holyoak 1998; Srygley et al. 2010). Pest outbreaks are often associated with dry years (White 1984), although extreme drought is unfavorable to insects (Hawkins and Holyoak 1998). Extremely wet years are also unfavorable (Fuhrer 2003). Under changing climate, environmental thresholds currently keeping some pests in check may be exceeded because of increased variability, making pest outbreaks likely to become more common as a result of increased climate variability. Phenological shifts and geographical range shifts in interacting species can be synchronous or asynchronous, and as a result may have important ramifications on pest population (Hance et al. 2007; Memmott et al. 2007; Hegland et al. 2009). For example, as a result of warming over the last century, the larch budmoth's range has shifted to the distributional limit of its host, dampening a millennium-long cycle in outbreaks of the moth (Johnson and McNicol 2010). As another example, the northward expansion of crop ranges may have altered aphid community composition.

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Aphids are important vectors of plant pathogens. Their short generation times make them likely to gain from global warming with a high risk of damage to crops. Range expansion of both the aphids and the pathogens they transmit will also result in increased genotypic diversity, making resistance to control efforts more likely to evolve (May and Dobson 1986). For example, green peach aphid populations are becoming more genetically variable in Scotland in association with warmer winters and earlier dispersal (Malloch et al. 2006). Projected changes in cereal aphid abundance in Canada in 2080 were temperature dependent, with increases in aphid populations predicted in more northerly latitudes or coastal regions, whereas southern or central regions had projected decreases, depending on the climate model (Newman 2006). Note that these projections are very different from the uniform decrease in cereal aphid abundance projected for southern Great Britain due to interactions of increased CO2 and limited N in a region that will experience greater drought (Newman 2005); projections of the response of an aphid parasitoid to climate change in Great Britain did not qualitatively alter the projections for the effects of climate change on the parasitoid's cereal aphid hosts (Hoover and Newman 2004).

With more pests shifting northward, generation times decreasing, and abundances increasing in the future, management costs are expected to increase due to more frequent application of pesticides.

For example, pesticide applications to control lepidopteran pests (e.g., moths) on sweet corn decrease with increase in latitude from 15 to 32 times per year in Florida, four to eight times per year in Delaware, and zero to five times per year in New York (Hatfield et al. 2011). It can also be expected that resistance to chemical control agents will evolve more rapidly because of the increased genotypic diversity that comes with pest insects' range expansion and greater numbers of generations of particular pests undergoing selection for resistant forms each year (May and Dobson 1986). Crop diversification and landscape management for natural pest control can result in greater suppression of pest outbreaks and pathogen transmission in a changing climate (Lin 2011). It is also likely that some biological control agents will become less effective due to mismatched sensitivity between agent and effects on pests due to changes in the environment that increase pest resistance. For example, with increases in temperature, the vine mealybug is projected to find refuge from parasitoids introduced for its control in California vineyards, as the parasitoids cannot survive under increased temperature (Gutierrez et al. 2008). Thus, the performance of candidate biological control agents under changing climate conditions will need to be assessed prior to selection and use.

Plant Pathogens

With non-vector-borne pathogens, plant pathogen responses to climate change must be considered within the context of a "disease triangle" that involves the pathogen, the host, and the environment; together these component parts determine whether a disease, itself a process, will occur (Agrios 2005). With vector-borne pathogens, the vector must be included in the disease triangle, with the microbial pathogen, the host, and the vector all interacting separately with the environment (e.g., Thresh 1983). In addition to having the basic components – pathogen, host and vector – as the required drivers of plant disease, plant pathogens and their vectors are influenced by other factors that complicate our ability to predict pathogen movement, incidence, severity, and evolution (Van der Putten et al. 2010).

Under current climate conditions, even with efforts to manage disease in place, crop losses to pathogens are estimated to be approximately 11 percent of overall worldwide production (Oerke 2006). Pathogen growth and reproduction can be evaluated independently with regard to the epidemiological parameters necessary for disease development (i.e., cardinal temperatures and responses to individual atmospheric influences). These effects have been determined for some pathogenic viruses, fungi, and bacteria, leading to weather-based decision-support models designed to address seasonal production issues and disease management protocols (Jones et al. 2010; Savary et al. 2011). One of the first comprehensive reviews of the potential effects of climate change on plant disease recognized that it would most certainly affect plant disease at many levels of complexity, although generalizations would be difficult to make (Coakley et al. 1999). More than 10 years later, this remains true, in spite of significant progress in defining parameters potentially driving plant disease processes in a changing climate.

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Increasing temperature may cause plant stress or may decrease plant stress depending on whether a crop is being grown in its optimal range or near a heat-tolerance threshold. Unfortunately, rarely does a single plant-growth or -health factor change as a result of climate change. When a combination of changes exist that result in temperatures, for example, that are no longer ideal for the crop host, this effect can be compounded when the change coincidently favors increased growth, formation of spores, earlier initial infection, shorter latent periods, or increased rates of disease progress (Campbell and Madden 1990).

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Livestock Pathogens

Climate change may indirectly affect animal production by altering the frequency, intensity, or distribution of animal pathogens and parasites. Climate affects microbial density and distribution, the distribution of vector-borne diseases, host resistance to infections, food and water shortages, or food-borne diseases (Baylis and Githeko 2006; Gaughan et al. 2009; Thornton et al. 2009). Earlier springs and warmer winters may allow for greater proliferation and survivability of pathogens and parasites. For example, bluetongue was recently reported in Europe for the first time in 20 years (Baylis and Githeko 2006). Regional warming and changes in rainfall distribution may lead to changes in the spatial or temporal distributions of diseases sensitive to moisture, such as anthrax, blackleg, hemorrhagic septicemia, and vector-borne diseases (Baylis andGitheko 2006). Climate change also may influence the abundance and/or distribution of the competitors, predators, and parasites of vectors themselves (Thornton et al. 2009). Hotter weather may increase the incidence of ketosis, mastitis, and lameness in dairy cows and enhance growth of mycotoxin-producing fungi, particularly if moisture conditions are favorable (Gaughan et al. 2009). However, no consistent evidence exists that heat stress negatively affects overall immune function in cattle, chickens, or pigs.

Conclusions: Climate change effects on weeds, insect pests and pathogens

Climate and climate change affect agriculture directly through the immediate effects of temperature, precipitation, and CO2. The growth and development of crops, rangelands, and livestock are also influenced indirectly by climate change, through its actions upon weeds, insects, and disease. These variables interact with one another to further influence agricultural outcomes. The complexities of the crop-climate-environment interactions make projecting the net outcome of climate change difficult. Agricultural responses to climate change depend on the specific environmental and agroecosystem conditions, in combination with the characteristics of a given agricultural product.

<u>Climate Change Effects on Agricultural Soil Resources</u>

(From Walthall et al. 2012: 53-56)

Soils provide ecosystem services that are necessary to society and the survival of life on the planet, including our own species. The roles soils play in delivering ecosystem services include nutrient cycling and the delivery of nutrients needed by growing plants. Soils act as a water filter and reservoir, purifying water as it passes through the soil substrate, and oftentimes providing water storage for later plant uptake. Soils also provide a structure for supporting plants and animals. They regulate climate through processes of carbon sequestration and uptake of other greenhouse gases. They contribute to conservation of ecosystem biodiversity and provide a direct source of human resources such as important minerals, peat, and clay (Dominati et al. 2010).

A few of the many important ecosystem services provided by soils include provision of food, wood, fiber, and raw materials; flood mitigation; recycling of wastes; biological control of pests; provision of the physical support for roads and buildings, as well as cultural services, which include both general aesthetics and a sense of place (Dominati et al. 2010). Healthy soils have characteristics that include the appropriate levels of nutrients required for production of healthy plants, moderately high levels of organic matter, a structure that has a good aggregation of primary soil particles and macro-porosity, moderate pH levels, thickness sufficient to store adequate water for plants, a healthy microbial community, and absence of toxicity.

It may be possible to draw inferences about the effects of climate change on agroecosystem services from observations about soil erosion and herbicide and nutrient movement from the edge of fields into adjacent areas. Erosion is a primary source for soil particles and agrochemicals transported from agricultural fields to streams and other water bodies. Under changing climate, some regions will experience greater drying, while other areas will have more intensive rainstorms or increased rate of snow melt – each of these factors may increase soil erosion. Movement of chemicals and soil material will affect the quality of water and will be affected by changes in the intensity of meteorological events. As soil erosion changes under climate change, so does the potential for associated offsite, non-point source pollution. Riparian buffers and wetlands often serve as sinks for pollutants moving from upland fields (Hill 1996; Mayer et al. 2007; Vidon 2010), thus making them important components in possible conservation practices for climate change adaptation in cases where offsite, non-point pollution is a concern.

Several processes, both natural and anthropogenic, act to degrade soils. These processes include erosion, compaction, salinization, toxification, and net loss of organic matter. Of these, soil erosion is the effect most directly affected by climate change and also the most pervasive. Soil erosion is a natural process and occurs regardless of human activity; however, human activities, including intensive agriculture, have caused accelerated erosion across many regions of the planet, including the United States (Montgomery 2007). Excessive erosion rates decrease soil productivity, increase loss of soil organic carbon and other essential nutrients, and reduce soil fertility (Quine and Zhang 2002; Cruse and Herndl 2009). The major factors affecting soil erosion are: (1) erosive effects of rainfall, irrigation, snowmelt, and wind; (2) plants, cropping, and management; (3) soil erodibility; (4) conservation practices; and (5) topography. Of these, climate change will most likely have the greatest effects on the first three, however strategies for adaptation to climate change effects generally are related to conservation practices (Delgado et al. 2011).

The most direct effect of climate change on rainfall-driven erosion is related to rainfall's erosive power (Favis-Mortlock and Savabi 1996; Williams et al. 1996; Favis-Mortlock and Guerra 1999; Nearing 2001; Pruski and Nearing 2002a, 2002b). The power or ability of a storm or series of precipitation events to cause soil erosion, or rainfall erosivity, is highly correlated with the interaction effect of storm energy and maximum prolonged precipitation intensity (Wischmeier 1959; Wischmeier and Smith 1965; Nearing et al. 1990; Nearing et al. 2005). With regard to erosivity, the dominant variable is rainfall *intensity*, which is the amount of rainfall reaching the soil surface per unit time, rather than total rainfall *amount* (Nearing et al. 2005). If both rainfall amount and intensity were to change together in a statistically representative manner, assuming temporally stationary relationships between amounts and intensities, the predicted erosion rate would increase on the order of 1.7 percent for every 1 percent increase in total rainfall (Pruski and Nearing 2002b)

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For parts of the Northern United States, including 4 million hectares of cropland in the northwestern wheat region, soil erosion is linked to snowfall amounts, snowmelt, and thawing soils (Van Klaveren and McCool 2010). Snow-associated erosion rates may be particularly high when snowmelt or rainfall occurs on thawed soil overlying a frozen layer of soil underneath (Zuzel et al. 1982; Schillinger 2001). Recently thawed soil is highly erodible because of the freezing effect on soil structure and aggregation, which increases soil erodibility, but equally or more importantly because of high moisture content and low soil water suction (Van Klaveren and McCool 2010). Although some process-based and plot-scale research has taken place, there is a general lack of knowledge about the rates of soil erosion associated with snowmelt or rain-on-thawing-soil erosion on a regional or national basis. A potential effect of climate change is associated with a change from snowfall to rainfall. If decreased days of snowfall translate correspondingly to increased days of rainfall, erosion by storm runoff is likely to increase. The potential trends of snow-induced erosion and the effects of snow-melt on thawing soils have not been assessed.

Wind erosion rate is a function of the wind velocity, soil moisture content, soil surface roughness, soil structure, field length, and vegetation characteristics (Chepil and Woodruff 1954; Skidmore 1965; Skidmore et al. 1970; Ravi et al. 2011). The primary region of concern for wind erosion on U.S. croplands stretches across the Great Plains, from Texas north to Montana, North Dakota, and western Minnesota (USDA 2010b). Additional areas of concern include the Northwestern United States (Washington and Idaho) and scattered areas of the Intermountain West. Areas of high wind erosion also occur on grazing lands in the arid and semi-arid regions of the Western United States. Munson et al. (2011) have suggested that wind erosion will increase on grazing lands of the Southwestern United States because of increased aridity and associated reductions of vegetation cover. Major changes of wind erosion rates driven by climate change would likely be associated with local or regional changes in vegetation and soil moisture, however there are no published studies available that estimate the potential increases in future wind speeds.

Increased wind is also likely to increase wildfire incidence, which in turn will increase wind and water erosion rates due to the drastic reductions in ground cover associated with burns (Sankey et al. 2012). There have been declining trends in near-surface wind speed over the last several decades (Pryor et al. 2009), and model projections indicate that these trends of decreasing wind speed will continue in the future (Segal et al. 2001). This may lead to a decrease in evapotranspiration in cropping regions and also reduce the potential for wind erosion.

Agricultural producers, in response to climate change, will change the types of crops planted and crops management. Changes in production can have effects on soil erosion that may be greater than other effects of climate change. Exactly how such changes occur will be a complex function of changing precipitation and temperature regimes, atmospheric CO2 concentrations, economics, and plant genetics, among other factors. Southworth et al. (2002a,b) used global circulation model output (from the U.K. Hadley Centre HadCM2 model) with various crop models to evaluate potential changes in wheat, corn, and soybean production in Indiana, Illinois, Ohio, Michigan, and Wisconsin by the mid-21st century. The studies projected significant changes in planting and harvest dates, which certainly have the potential to influence erosion rates. Those results were then coupled with economic modeling (Pfeifer and Habeck 2002; Pfeifer et al. 2002) to create scenarios of producer adaptation. Taking all of this information together, O'Neal et al. (2005) conducted a study of climate change effects on projected runoff and soil erosion in the five States with changes in corn-soybean-wheat management, which included projected changes in the percentage of the three crops grown across the region, biomass production, planting dates, tillage dates, and harvest dates, as well as changes in temperature and precipitation patterns themselves. The results of the simulations projected runoff increases from 10 percent to 310 percent and soil loss increases from 33 percent to 274 percent from 2040 to 2059 relative to 1990 to 1999 for 10 of the 11 sub-regions of the study area due to reduction in projected corn biomass (and hence reduced crop residue) production and a shift in crop percentages toward soybeans, which are much more erodible crops than either corn or wheat (Wischmeier and Smith 1978). These projections are uncertain, however they indicate the large potential magnitudes of erosion rate changes that could occur with changes in production.

Future changes in the climatic drivers of soil erosion and farmer management adaptations to a changing climate (e.g., crop selection and dates of planting, harvest, and tillage) have the potential to greatly influence soil erosion rates, with a general trend in the United States toward higher rates of erosion. Agricultural production systems will change under a changing climate, but if production systems are implemented congruently with appropriate conservation management systems as they inevitably shift in response to climate change, the effects of most increased precipitation amounts and intensities on soil erosion can be alleviated (Delgado et al. 2011; Lal et al. 2011). The additional benefit of conservation management is the contribution to climate change mitigation by sequestering atmospheric CO_2 through increased organic matter in the soil and by reducing emissions of nitrogen trace gases such as N_2O through improved rate, timing, and method of fertilizer application (Delgado and Mosier 1996; Eagle et al. 2010; Lal et al. 2011).

Conservation tillage, crop residue management, cover crops, and management of livestock grazing intensities have the potential to reduce much or all of the acceleration of soil erosion rates that might occur under a more intense rainfall regime associated with climate change (Delgado et al. 2011). In addition, these techniques in general enhance soil quality by increasing SOM content and improving soil structure (Karlen et al. 1994a, 1994b; Lal 1997; Reicosky 1997; Weltz et al. 2003; Weltz et al. 2011), both of which improve the water-holding capacity of soils and hence could be key to adaptation for water management during drought.

A newer method in the conservation toolbox is the use of precision conservation, an approach that targets conservation practices to places on the landscape where they will be most effective. Precision conservation takes into account the temporal variability of weather events, the variability of surface flows, the variability of slope gradient and length, and the variability of soil and chemical properties of soil across the landscape (Berry et al. 2003; Mueller et al. 2005; Schumacher et al. 2005; Pike et al. 2009; Luck et al. 2010; Tomer 2010). Precision conservation techniques may be particularly well adapted to application under the increased variability and rainfall intensities associated with climate change. Among the expected effects of climate change is greater frequency of extreme precipitation events. Since soil variability, variations in hydrology, and variability in surface terrain affect erosion rates, extreme precipitation events will accentuate variation in erosion rates across any given field, increasing the erosion rates at given locations across the field where surface flows will be spatially more concentrated.

<u>Climate Change Effects on Ecosystem Services Including Pollinators</u>
(From Walthall et al. 2012: 59-61)
Agricultural systems offer a range of potential ecosystem services, including pollination, biological pest control, nutrient cycling, hydrological cycling, greenhouse gas and carbon sequestration, and biodiversity. More than simply providing services, agricultural systems also utilize the available ecosystem services and processes for their function, which increases system complexity. + + +

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Ecosystem services reliant on biological interactions may be particularly vulnerable to climate change if the interacting species respond differently to environmental change (Tylianakis et al. 2008; Hegland et al. 2009). Crop pollination is an important biologically mediated service, because 75% of the leading global food crops are pollinated by animals (Klein et al. 2007). The phenology of many ecological processes is modulated by temperature, making them potentially sensitive to climate change. Mutualistic interactions such as pollination may be especially vulnerable due to the potential for phenological mismatching (i.e., asynchrony in its activity period) if different taxa do not respond similarly to temperature changes (Root et al. 2003). In particular, if pollinators and flowering plants respond differently to warming temperatures, this could result in phenological mismatches with negative outcomes for both groups of organisms.

An analysis was conducted on climate-associated shifts in the phenology of wild bees, the most important pollinators worldwide, and compared to published studies of bee-pollinated plants over the same time period (Bartomeus et al. 2011). Over the past 130 years, the adult activity period of 10 bee species from northeastern North America has advanced by a mean of 10.4 ±1.3 days. Most of this advance has taken place since 1970, paralleling global temperature increases. When compared to the shifts in plant phenology over this time period, the changes in phenological rates are not distinguishable from those of bees, suggesting that bee emergence is keeping pace with shifts in host-plant flowering, at least among the generalist species investigated in this study. However, the case could be different for bees that specialize on particular plants, and plants that specialize on particular bees; such taxa have not yet been investigated.

In addition to shifts in bee phenology, climate change may also affect the daily activity patterns of bees. Potential future effects of climate warming on crop pollination services were evaluated utilizing data from 18 watermelon farms in New Jersey and Pennsylvania between 2005 and 2010 (Rader 2012, personal communication). To assess this interaction, pollen deposition and daily activity patterns of seven dominant pollinator taxa were evaluated as a function of temperature and time of day. Future plant-pollinator interactions were then simulated based on two Intergovernmental Panel on Climate Change (IPCC) climate change scenarios (one assuming low greenhouse gas (GHG) emissions, the other assuming high emissions) at two future time periods (2050 and 2100) to determine the effect of rising temperatures on pollinator activity patterns and subsequently on crop pollination services. Under current conditions, pollinators differ in their activity patterns at varying temperatures within a day. Model predictions suggest that under future, warmer climate scenarios, five of the seven taxa should provide increased pollination services. Conversely, the honeybee, which is the dominant crop pollinator worldwide, and one native bee species, is predicted to provide less pollination under projected future warmer conditions. The differential responses among bee species to rising temperatures should help stabilize pollination services, as the decline in services by some taxa is buffered by the increase in others. It is important to note that native pollinator species provide this buffering effect and that the study system where the work was done has high levels of crop pollination (about 60 percent) from native bees. In other, more intensive agricultural systems where native bees are absent, the honey bee is the primary crop pollinator. The results of this study suggest that in such systems, pollination will decline as the climate warms.

+ + +

Climate Change Effects on Agricultural Production, Conclusions

(From Walthall et al. 2012: 97-98)

The direct and indirect effects of changing climate create threats and opportunities for U.S. agriculture. The direct effects of changing temperature and precipitation patterns are widely acknowledged and investigated. Producers and researchers have traditionally faced challenges of temperature and moisture changes with success. However the short-term high variability of weather events currently being experienced are outside of the realm of experience for the agricultural community. Given a continued trend of this variability, a shift of management focus from mostly average conditions to that of focus on managing average plus extreme conditions may well be advised. The addition of "event duration" or "maximum tolerable change per day," especially for sensitive growth stages, are potential additions to threshold tables defining the temperature and moisture limits for specific crops. Dealing with the weather manifestations of climate change will be integral to decisionmaking for future producers, more so than for that of past generations.

The complex nature of the agroecosystem means that effects of climate change on system components will vary broadly across geographies and temporal scales. Assessing the full effect of climate change on U.S. agricultural products will require integrated studies that incorporate the nuances of ecosystem function such as soil make-up, changes in timing of runoff, and effects of changing temperature patterns and CO_2 concentrations, together with factors related to production economics, management strategy approaches and implementation, and adaptation practices. Such studies will also feed creation of models that may more accurately project future changes and assess effects of land-use or water-resource changes that may affect crops, and assist with developing strategies that can provide insights on increasing efficient use of available resources. In addition, adaptation management practices would benefit from further research on adaptive cultivars and crop genetics so as to mitigate projected declines in future yields by taking better advantage of climate-driven shifts in ecosystem characteristics through breeding for physiological pathways that increase resilience to climate stressors. Lastly, managing for changing climate will benefit from further research into technologies that improve management of agricultural products through further automation of processes and tools, sensor development, and enhancement of information technologies. Advancing these research needs will assist those working in the realm of U.S. agriculture by providing both pragmatic solutions while potentially reducing costs related effects of climate change on agricultural production.

3.11 Agroforestry

(From *Agroforestry*: USDA Reports to America, Fiscal Years 2011–2012)

The United States Department of Agriculture (USDA) defines agroforestry as "the intentional mixing of trees and shrubs into crop and animal production systems to create environmental, economic, and social benefits" (USDA 2015). Agroforestry contributes to biodiversity by supporting habitat provision, connection, and conservation, as well as germplasm preservation. In the United States, agroforestry can play a role in providing wildlife habitat and connectivity, increasing plant diversity in agricultural areas, providing food and habitat for pollinators, providing and supporting aquatic habitats, and reducing erosion and nutrient run-off. Agroforestry can also support rangeland by increasing plant diversity and providing animals with shelter from wind.

There are five widely recognized categories of agroforestry practices in the United States:

- *Windbreaks.* Planted across the Great Plains states in the early 1900s, windbreaks were designed to reduce soil loss from wind erosion. Since then, this term has expanded to include shelterbelts, hedgerows, and living snow fences designed to shelter crops, people, animals, buildings, and soil from wind, snow, dust, and odors. Windbreaks are still most commonly found across the Great Plains region.

- *Conservation buffers.* Established along rivers and streams and in upland areas, conservation buffers consist of trees, shrubs, and/or grasses that filter farm runoff and reduce soil erosion. Conservation buffers are established in many areas of the United States. In recent years, USDA and other agencies of the U.S. government have been working hard to encourage conservation buffer establishment in the Chesapeake Bay watershed, which includes all or parts of the states of Maryland, Delaware, Virginia, West Virginia, and Pennsylvania.

- *Silvopasture.* By combining tree management with livestock production on a single piece of land, silvopasture can increase the efficiency of land use and farmer incomes, as well as provide benefits such as increased carbon sequestration. Anecdotal evidence indicates that silvopasture is most commonly practiced in the Southeastern United States, but is also taking place in other parts of the country including New England.

- *Alley cropping.* Planting crops between rows of trees can help to augment landowner income before the trees are mature enough to harvest and/or produce fruit, berries, or nuts.

While considerable research has been devoted to this practice in the United States, it has not been widely adopted by landowners.

- *Forest farming.* Also referred to as multi-story cropping, forest farming involves the intentional production of food, herbal, botanical, or decorative crops under the protection of a managed forest canopy. Forest farming can help to provide an additional source of income for private forest owners, and reduce pressures on local forest products that are being wild harvested. Forest farming may be on the rise in the United States, due to increased public interest in the consumption of wild products and the local food movement.

There is little nationally-consistent information on the status and trends of agroforestry in the United States. Because agroforestry practices are relatively small, they are not included in the primary national inventories conducted for forestry and agriculture. However, some indication of the level of adoption of each practice can be gleaned from a number of sources.

The USDA Natural Resources Conservation Service and the Farm Service Agency provide some data on the relative importance of each agroforestry practice in the United States. From 2008 until 2012 these two agencies provided financial and technical support that established 336,000 acres of windbreaks, riparian forest buffers, and alley cropping; 2,000 acres of silvopasture; and 500 acres of forest farming. As indicated in Table 3-3, which includes more detailed figures for 2011 and 2012, riparian forest buffers and windbreaks are the most common agroforestry practices adopted with USDA assistance. This data does not include agroforestry acres established without USDA assistance or prior to 2008 and with assistance.

Additional information on agroforestry comes from surveys of private forest owners. In the most recent national survey of "family forest owners" (families, individuals, trusts, estates, family partnerships, and other unincorporated groups of individuals that own forest land), 14 percent of family forest owners reported harvesting nontimber forest products from their land. Because the data does not indicate whether these products were intentionally produced or wild harvested, we do not know the percent of owners practicing forest farming.

Table 3-3 Specific: agroforestry acres/miles applied* FSA and NRCS conservation programs

Practice	Unit	FY 2011	FY 2012
Windbreaks*	Miles	2,169	1,789
Riparian forest buffers**	Acres	58,684	76,751
Alley cropping	Acres	203	55
Forest farming	Acres	212	49
Silvopasture	Acres	583	332

FSA = Farm Service Agency. FY = Fiscal Year. NRCS = Natural Resources Conservation Service.
** Includes windbreaks, shelterbelts, hedgerows, and living snow fences (practices CP 5, CP 16, CP 17, 380, 650, and 422). ** Includes riparian forest buffers and bottomland hardwoods (practices CP 22, CP 31, and 391).*

Another source of information on agroforestry is the United State Census on Agriculture. In 2012, the United States Census on Agriculture included, for the first time, a question on agroforestry, asking producers whether they were practicing alley cropping or silvopasture. While only about 2,725 respondents answered positively to this question, we know through USDA programs that a greater number of landowners may be practicing these techniques. The map in Figure 3-17, containing the number of positive responses in each state, shows the relative importance of these practices in the country. Of the seven states with over 100 land owners reporting the adoption of alley cropping or silvopasture, five are in the Southeastern United States and two are in the Northeast.

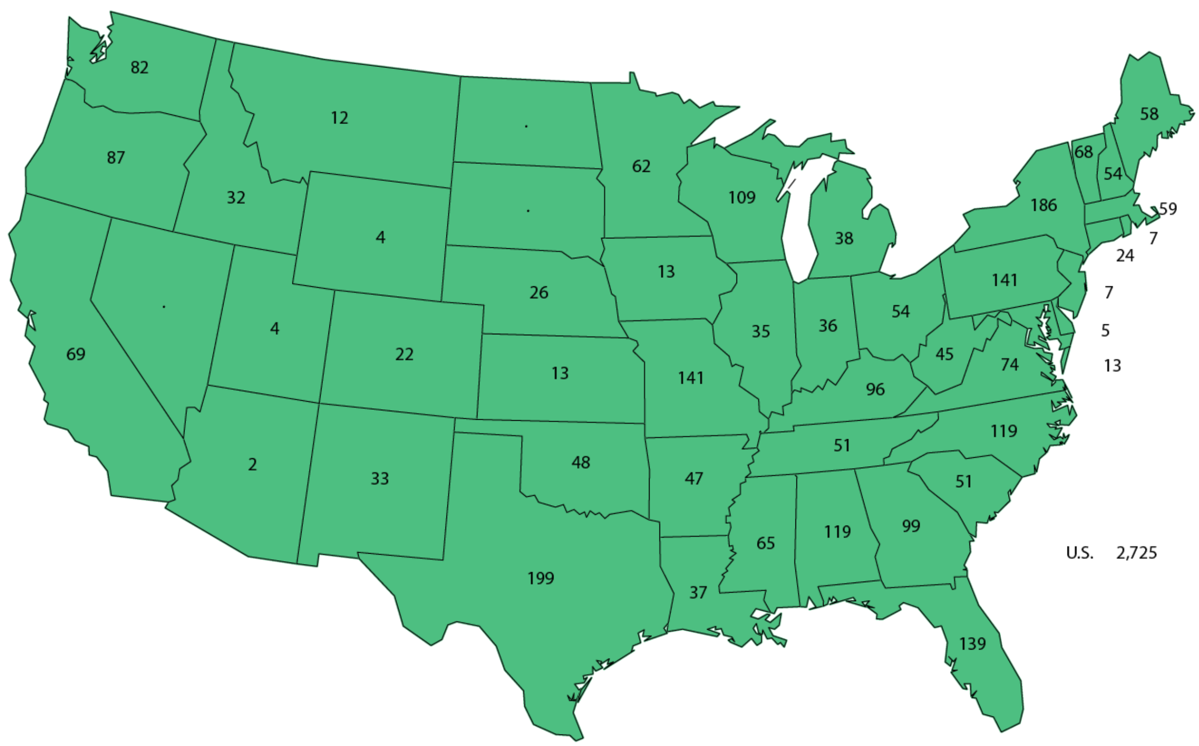
These types of data sources provide only patchy information on trends in agroforestry adoption or maintenance. Anecdotal evidence suggests that, due to the increasing influence of the local food movement and interest in wild harvested crops, land under forest farming could increase substantially in the future (Jose, Gold, & Garrett 2012). Natural resource conservation professionals in the Great Plains region (North Dakota, South Dakota, Nebraska, Colorado, Kansas), however, have observed a widespread removal of windbreaks and riparian buffers by agricultural producers in response to exceptionally high crop prices between 2008 and 2012.

The practice of silvopasture may increase in the Southeastern United States with USDA assistance. In the 1990s and mid-2000s, many producers in the Southeast signed contracts agreeing to plant and maintain trees on their farms for at least 10 years, in exchange for financial payments. As these contracts expire, practicing silvopasture may provide an incentive for producers to retain tree cover, while benefitting economically from grazing livestock. It is estimated that in 2012, contracts expired that had covered about 400,000 acres of land planted in trees.

Pressures on agroforestry systems are similar to pressures on all privately-owned and managed farm and forestlands in the United States. A key determinant of trends in acreage under agriculture and forest is urbanization. In addition, anecdotal information indicates that as prices rise for monoculture crops such as corn, producer interest in retaining windbreaks and riparian buffers decreases.

Figure 3-17 Farms practicing Alley Cropping or Silvopasture, 2012*

Source: 2012 Census of Agriculture



*Numbers in each state indicate the number of respondents who indicated positively that they practice agroforestry

The United States Department of Agriculture has supported agroforestry in a number of ways. In 1990, the USDA formed the National Agroforestry Center, which has locations in Lincoln, NE, and Blacksburg, VA. The National Agroforestry Center conducts agroforestry research and demonstrations and works through a national network of partners. The USDA created an Agroforestry Strategic Framework in 2011 to encourage USDA agencies to support agroforestry research and technology transfer; formed an Interagency Agroforestry Team and Executive Steering Committee to implement the strategic framework; and formed multistate interagency agroforestry working groups in the Chesapeake Bay, Midwest, and Pacific Islands. In 2013 the USDA passed a Departmental Regulation that established agroforestry policies across the USDA.

An assessment of seven USDA agencies indicates that approximately $333 million was dedicated to agroforestry activities in FY 2011–12. The majority of these funds were devoted to technical and financial assistance to landowners. Windbreaks and riparian buffers accounted for 99 percent of this assistance while silvopasture, alley cropping, forest multicropping, and edible forest buffers accounted for the rest.

USDA programs that financially support agroforestry research and implementation include:

- Environmental Quality Incentives Program
- Conservation Stewardship Program
- Conservation Innovation Grants
- Sustainable Agriculture Research and Education grants and trainings

During fiscal Year 2011–2012, USDA agencies supported 69 agroforestry research projects that were focused on the following 5 areas (number of projects):

- Natural Resources, Ecosystem Services, and Environmental Markets (22), with specific focus on water (6), pollinators (1), soil (3), air (1), carbon (7), and multiple environmental services (4).
- Agroforestry Systems (31), with specific focus on silvopasture (8), alley cropping (3), forest farming (8), windbreaks (1), and edible tree crops (9).
- Climate Change Resiliency (2).
- Bioenergy (7).
- Economics and Profitability (7).

The U.S. Fisheries and Wildlife Service also supports agroforestry through a grant program called Partners for Fish and Wildlife.

<u>Impacts of agroforestry on biodiversity in the United States</u>

While there are numerous studies of environmental benefits of agroforestry worldwide, there are no syntheses of this topic for the United States. The following description of environmental benefits is from a synthesis conducted by Shibu Jose in 2009, based on a review of studies across the world. Studies reviewed for the United States are referenced here.

In his review, Jose identifies four categories of environmental benefits from agroforestry: 1) carbon sequestration, 2) biodiversity conservation, 3) soil enrichment, and 4) air and water quality. A short summary of each is provided below:

Carbon sequestration. Jose reviewed several carbon sequestration studies that concerned tropical agroforestry systems, many of which do not apply to the United States. However, the general conclusion that "trees or shrubs in agroforestry systems can increase the amount of carbon sequestered compared to a monoculture field of crop plants or pasture" likely holds for the United States as well (Jose 2009, p. 2). Udawatta and Jose estimated that the United States could potentially sequester 530 teragrams of carbon per year through expanded agroforestry practices (Udawatta & Jose, 2012).

Researchers in the United States are developing a model to estimate the biomass and carbon content of trees used in agroforestry in the United States, based on similar estimates for forest-grown trees (Hou et al. 2011; Zhou et al. 2011). This work will greatly enhance our ability to estimate carbon sequestration benefits of trees in agroforestry systems.

Biodiversity conservation. Studies reviewed for the United States indicate that: 1) the density and diversity of insect populations varies with the use of ground cover and increases with the use of windbreaks; 2) the use of annual legumes and grasses as cover crops can support arthropods, such as lady beetles (Coleoptera: Coccinelliadae); 3) the addition of woody habitats such as windbreaks and buffers to agricultural landscapes increases the diversity of plant composition and structure which in turn can lead to increased biodiversity overall. Agroforestry provides habitat and food for pollinators, which in turn supports agricultural production (National Agroforestry Center 2015). Other wildlife also benefit from agroforestry due to increased habitat area and connection. Riparian forest buffers can reduce pollution, decrease erosion, and provide aquatic habitat for fish and mussels (National Agroforestry Center 2014). In the United States, riparian forest buffers are common in the North Central region (Jose, Gold, & Garrett 2012).

Soil Enrichment. While there is a large body of literature on soil enrichment in the tropics, focused on the role of nitrogen-fixing trees in enhancing soil fertility, little has been done in the United States. Studies conducted in the United States indicate that intercropping traditional agricultural crops such as maize, soybean, and cotton, with tree species in an agroforestry system can lead to increased total nitrogen content (Red alder and maize, Oregon); enhanced soil organic matter and microbial biomass (cotton and pecan trees, Southern region); and improved soil porosity (agroforestry buffers and maize/soybean, Midwest region).

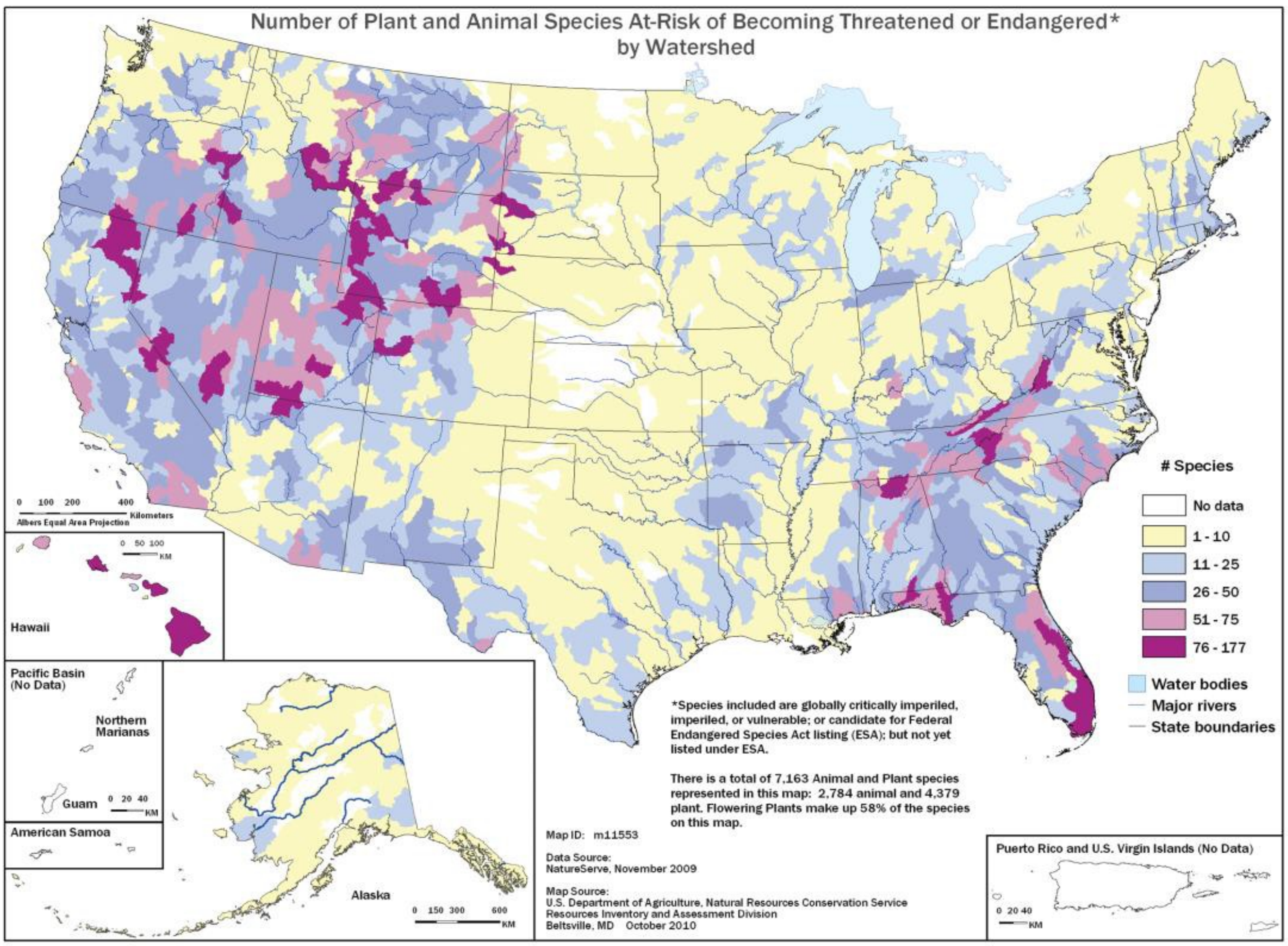
Improved air and water quality. Agroforestry practices can improve air and water quality. Windbreaks and shelter belts absorb carbon dioxide, produce oxygen, reduce soil erosion by decreasing wind speed, and help mitigate the transport of odors from intensive livestock operations and surrounding areas. Agroforestry practices, most notably riparian buffers, can help to reduce the amount of agricultural chemicals and fertilizer transported from farmlands to waterways.

Studies reviewed in the Unites States indicate that 1) when planted strategically, shelterbelts can be an economical, effective means for controlling livestock odor (Midwest); 2) riparian buffers can significantly reduce nitrogen flow from an agricultural field (switchgrass; Panicum virgatum, Iowa); 3) the incorporation of trees into agricultural systems allows more efficient use and recycling of nutrients, due to the deeper root systems and longer growing periods of trees (pecan-cotton, Florida; slash pine, Pinnus elliottii, in pasture, Florida).

4. State of Biodiversity for Food and Agriculture

The United States has more than 200,000 identified species of plants and animals. The National Heritage Network has developed a consistent method for evaluating the health of both species and ecological communities; species are classified as secure, apparently secure, vulnerable, imperiled, critically imperiled, possibly extinct, or presumed extinct. Based on this classification, approximately one-third of the more than 22,600 species that have been evaluated through the National Heritage Network are considered at-risk or of conservation concern (i.e. classified as other than secure or apparently secure). And of these, 2 percent of assessed species are possibly or presumed to be extinct (Stein et al. 2000, Heinz Center 2008). Figure 4-1 shows the number of plant and animal species at risk of becoming threatened or endangered by watershed.

Figure 4-1 Number of plant and animal species at risk of becoming threatened or endangered by watershed, 2009



Source: NRI, NRCS; RCA Interactive Data Viewer.

In terms of the gross number of species at risk, flowering plants make up the majority of at-risk species. In 2000, more than a third of the known 15,300 flowering plant species were considered at risk, translating to 5,090 species (Stein et al. 2000). On a proportional basis, however, freshwater animal species appear to be at greatest risk with 37 percent considered at risk (Heinz Center 2008). Specifically, nearly 70 percent of the nation's freshwater mussels, more than half of the crayfish species, and more than one-third of freshwater fishes are at risk (Stein et al. 2000). Moreover, nearly 29 percent of at risk freshwater species have declining populations, compared to 24 percent with stable populations and a mere one percent with increasing populations. Population trend data for the remaining 46 percent of identified at-risk vertebrate freshwater animals is unknown (Heinz Center 2008).

Agroecosystems have replaced much of the original grassland and wetlands in the Corn Belt, northern prairies and California's Central Valley; the original bottomland hardwood forested wetlands of the Southeast; and the sagebrush habitats of the western rangelands (USDA 2011c). As a result, agriculture is a significant driver of biodiversity trends in the United States.

Any analysis of the impact of agriculture on biodiversity is restricted by data availability. In the United States key trend data on biodiversity tracks four primary indicators:

- **Freshwater species**: Freshwater species are impacted by agriculture in two ways. First, agriculture impacts freshwater species through water diversions and stream alterations which can significantly alter freshwater habitat, and secondly agriculture impacts freshwater species as a result of pesticides, sediments and nutrients that run off from fields.
- **Birds**: Birds are an overall good indicator of ecosystem health and biodiversity. In particular, this report will focus on population trends in grassland and wetland birds. Grasslands are arguably the habitat most impacted by agriculture both through habitat conversion (over 71 percent of grassland having been converted to cropland), and through impacts of agricultural management practices. Similarly, the majority of wetland losses have been the result of agricultural conversions. By examining bird population trends in these two ecosystem types we can begin to understand the impact of agricultural systems on these ecosystems health and supporting ecosystem services as well as examine how agricultural systems can be managed in a way that continues to support biodiversity.
- **Pollinators**: In recent years North America has experienced an alarming decrease in populations of pollinators such as bats, bees and butterflies. Agriculture is both heavily dependent on the services provided by pollinators as well as a driver behind pollinator declines in many cases.
- **Soil Biodiversity**: Soil health is an indicator of soil biodiversity as healthy soil can support a diversity of microorganisms. Soil health includes many components such as maintaining soil organic matter, keeping soil in place, and maintaining healthy soils through crop diversity.

Trends in biodiversity for food and agriculture in the United States based on these indicators are mixed. Freshwater species, grassland birds and pollinators are experiencing downward trends, though declines in grassland birds have begun to flatten out and stabilize. Meanwhile, the United States has seen upward trends in wetland-dependent birds and in some indicators of soil health, in addition to holding wetland acres steady. The following sections examine these trends in more detail.

4.1 Freshwater species

Thirty-seven percent of freshwater species are at risk, highlighting the importance of freshwater habitats for species recovery. Agriculture is listed as a source of endangerment for 45 percent of fishes and 64 percent of mussels that are listed or proposed under the U.S. Endangered Species Act (USDA 2011c). There are marked geographic differences in the nature threats to aquatic species in the eastern versus the western United States. In the western states, altered hydrologic regimes as a result of agricultural withdrawals of surface water, together with invasive species are the major threats to aquatic species. For example, in California and Nevada where agricultural accounts for 77 and 78 percent of consumptive water use respectively, more than 15 percent of freshwater species are at risk (Cohen 2009; Singletary 2005; Heinz 2008).

In the eastern United States, agricultural nonpoint source pollution from pesticides, herbicides, nutrient runoff and sediment are the major causes of freshwater habitat degradation (Wilcove *et al.* 1998). Water pollution from all sources has been identified as a source of endangerment for many freshwater species, with 55 percent of at-risk fishes and 97 percent of at-risk mussels threatened as a result of declining water quality, primarily sedimentation (Wilcove *et al.* 1998 as cited in USDA 2011c). Sediment losses from agricultural fields, areas of timber harvest, urban areas and unimproved roads can impair local streams by decreasing water clarity and causing siltation. Reduced clarity interferes with feeding and can impact mussel behavior while siltation eliminates habitats critical for spawning, feeding and shelter of many aquatic species. In addition, nutrient pollution which is caused by fertilizer and manure runoff from farms can lead to algal blooms and reduced oxygen levels, can also impair freshwater habitats upon which at-risk species depend.

Box 4.1 The Oregon Chub

Focused conservation efforts involving the farming community, federal and state agencies, engagement with nonprofit organizations can yield results in species conservation. In February 2015, after one such effort, the Oregon Chub – on the Endangered Species List since 1993 – was delisted. The Oregon chub is a small minnow endemic to the Willamette River Valley of western Oregon.

Oregon chub are found in slack water off-channel habitats such as beaver ponds, oxbows, side channels, backwater sloughs, low gradient tributaries, and flooded marshes. The construction of flood control projects and dams, however, changed the Willamette River significantly, and prevented the formation of chub habitat and the natural dispersal of the species. Other factors responsible for the decline of the chub include: habitat alteration; the proliferation of non-native fish and amphibians; runoff from herbicide or pesticide application on farms; sedimentation; and unauthorized water withdrawals.

A broad spectrum of organizations and individuals made other key contributions to the chub's recovery, including the Confederated Tribes of Grand Ronde and their Tribal Fish and Wildlife Program, which helped evaluate the impacts of stream management options on the chub. The Army Corps of Engineers played a vital role in implementing many of the stream management improvements vital to the chub's recovery. USDA's Natural Resources Conservation Service protected 623 acres of chub habitat through Wetlands Reserve Program conservation easements. Professors and students from Oregon State University's Department of Fisheries and Wildlife completed some of the important underlying science to guide recovery efforts. And perhaps most crucially, dozens of private landowners in the Willamette River Basin stepped up and provided habitat on their land (Ashe 2015).

4.2 Birds

Bird population trends are often a barometer of broader ecosystem health and how it is changing. Birds are sensitive to environmental changes and can indicate trends in habitat quality, pollution, and biodiversity. A broad consortium of groups including the National Park Service, the U.S. FWS, the U.S. Forest Service, and the USGS contributed to the "The State of the Birds in the United States of America 2014" (North American Bird Conservation Initiative 2014). This report, the fifth since 2009, uses birds as indicators of ecosystem health by examining population trends of obligate species for a single habitat (all the bird species dependent primarily on that habitat for survival). It assesses the health of bird populations through a set of indictors, including a set of habitat indicators. Habitat indicators are based on the population changes of obligate bird species—those birds restricted to a single habitat—where long-term monitoring data is available. The 2014 report finds about an 8 percent decline in habitat indicator for Aridland birds since 2009 and a less than 5 percent decline for Eastern Forest and Western Forest birds. Habitat indicators improved for

Grasslands, Coasts and Wetland birds, with the Wetland habitat indicator increasing almost 20 percent from 2009.

The North American Breeding Bird Survey (BBS), conducted by the Biological Resources Division of the U.S. Geological Survey and volunteers throughout the country has provided information on a wide variety of bird populations since 1966. It provides valuable information on bird population trends over nearly five decades.

The sections below focus in on population trends in grassland birds and wetland birds because these bird habitats are most impacted by agroecosystems. Historical population fluctuations in grassland-nesting bird species have coincided with changes in land uses and agricultural practices, making grassland birds in particular a good indicator for the impact of agroecosystems on biodiversity. Similarly, population trends of wetland-dependent birds have are linked to agricultural impacts on wetlands.

<u>Grassland Birds</u>

Grassland birds, or those birds that rely on grassland habitats for nesting, are found in each of the 50 states and worldwide. Various species of waterfowl, raptors, shorebirds, upland gamebirds and songbirds rely on grasslands for nesting and other habitat functions. Many North American grassland-nesting bird species have experienced marked population reductions in recent decades (USDA NRCS 1999). Continued nationwide declines in some grassland-nesting bird species have increased awareness for the need to preserve, manage, and restore grassland habitat in order to recover and maintain viable grass-land-nesting bird populations.

The past 150 years have brought major changes to the character of native grasslands in both Eastern and Midwestern/Great Plains regions of the United States. Prior to European settlement, the predominately forested northeastern United States contained parcels of open grasslands (including those cleared by Native Americans) that supported populations of grassland birds. By the 1800s, grasslands were widespread in the northeast due to the forest clearing activity of European settlers to create pastures and hayfields (USDA NRCS 1999). The establishment of these agricultural grasslands was associated with increases in some grassland bird species populations (USDA NRCS 1999). In the Midwest and Great Plains regions, settlers found vast expanses of native grassland that had covered much of the landscape. Most of these grasslands were converted to agricultural fields and livestock pastures in the late 1800's and early 1900's as farmsteads and European settlement expanded westward (USDA NRCS 1999)

Today, native grassland habitats are the largest and most threatened ecosystems in North America with as much as 71 percent of grassland having been converted to cropland and 19 percent to urban areas. It is estimated that less than one percent of the native Tallgrass prairie remains as grassland while mixed-grass and short-grass prairie have been reduced to 20 to 30 percent of their former extents (Commission on Environmental Cooperation 2008; McCraken 2008). Grassland declines in the eastern United States have largely been the result of idled farmland reverted back to old field and second-growth forest. In addition, changes in dairy farming and suburban sprawl have contributed to declines in eastern grasslands (North American Bird Conservation Initiative 2014).

BOX 4.2 The NRCS Sage Grouse Initiative

In 2010, the U. S. Fish and Wildlife Service (FWS) designated the greater sage-grouse a Candidate species for protection under the Endangered Species Act (ESA). In that same year, the Natural Resources Conservation Service (NRCS) launched SGI to voluntarily reduce threats facing sage-grouse on private lands. Over the past 5 years, SGI has matured into a primary catalyst for sagebrush conservation across the West. SGI focuses on the shared vision of wildlife conservation through sustainable ranching, providing win-win solutions for producers, sage-grouse and 350 other obligate species. With 1,129 participating ranches in 11 western states, SGI and its partners have already invested $424.5 million and conserved 4.4 million acres, an area that is twice the size of Yellowstone National Park (USDA NRCS 2015).

Activities funded through this initiative include improving sage grouse habitat by remove successional trees on grassland that displace native cover and provide roosting for predators, in addition to marking fences in order to prevent in-flight collisions.

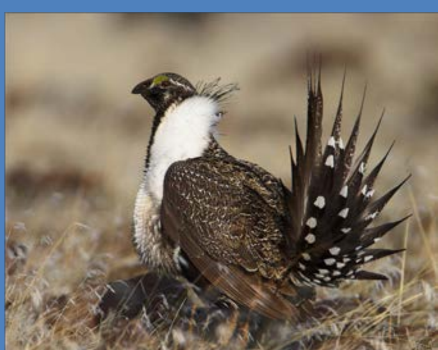


Photo Credit: Pacific Southwest Region U.S. Fish and Wildlife Service from Sacramento, US - Greater Sage Grouse/Wikimedia Commons

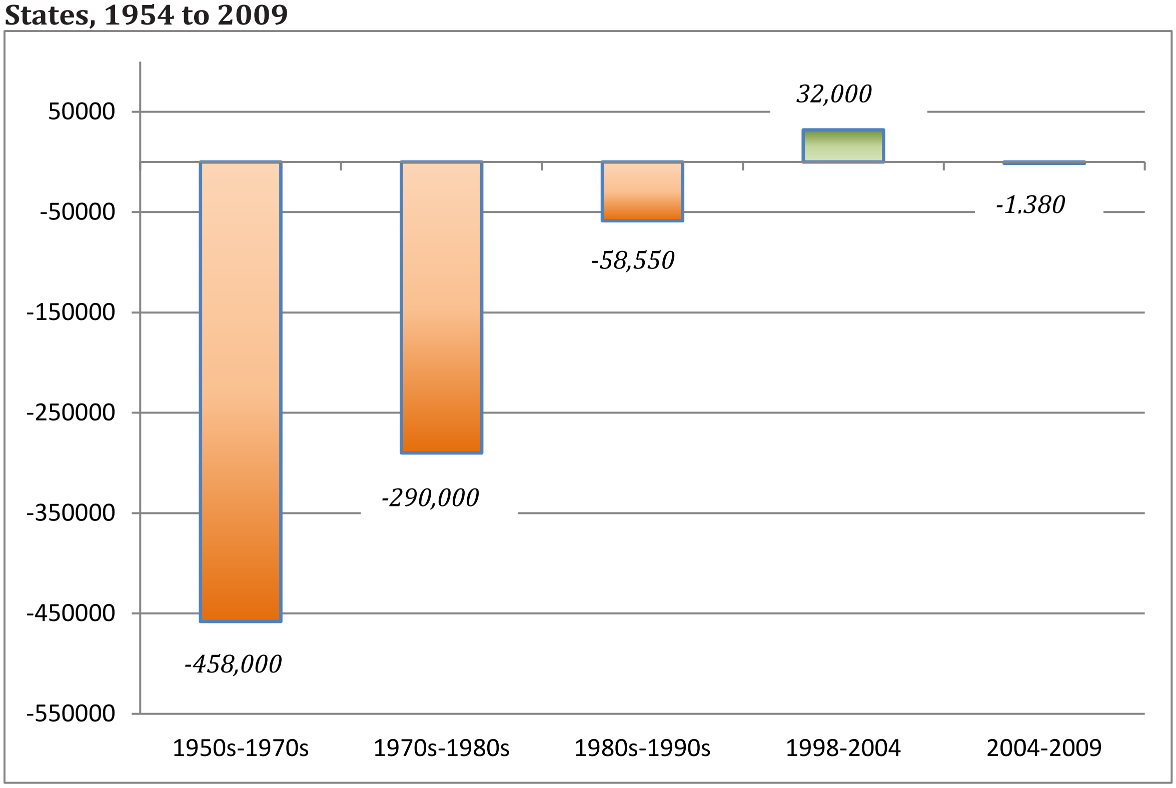
In the west, changes in agricultural practices with the advancement of modern machinery and an increasing demand for agricultural products reduced native grassland acreage (USDA NRCS 1999). Plowing of fields, removal of native grazers (bison), loss of wetlands, implementation of plantation forestry practices, and invasion of woody vegetation resulting from fire suppression have all contributed to significant losses of native grassland habitats (USDA NRCS 1999). Development of large farming operations in the Midwest and Great Plains has significantly changed the composition of grasslands; intensively managed crop fields and improved pastures have largely displaced native grasslands on most of the agricultural landscape (USDA NRCS 1999). In the Midwest, pasture and hayland is also being replaced by more intensively-managed row crops. On the high plains and other areas of the west, a larger percentage of the landscape remains grassland habitat and many of these rangelands are used extensively for grazing livestock (USDA NRCS 1999).

The Breeding Bird Surveys (BBS) reveal that grassland birds, as a group, have declined more than other groups, such as forest and wetland birds. And, according to the 2014 State of the Birds report, beginning in 1968, the grasslands indicator for 24 obligate breeding birds declined by nearly 40 percent (North American Bird Conservation Initiative 2014). There are many examples of population decline in grassland birds, most notably the 1932 extinction of the heath hen from the northeastern United States. Over the 25-year period 1966-1991, New England upland sandpiper and eastern meadowlark populations declined by 84 and 97 percent, respectively. The greater prairie-chicken experienced an average annual rate of decline of over 10 percent during this same 25-year period. Beginning in the 1990's, however, grassland bird declines began to flatten out and stabilize; reflecting concerted conservation efforts, primarily through U.S. Farm Bill programs (North American Bird Conservation Initiative 2014). From 2009 to 2014, the State of the Birds report found an increase in the grassland habitat indicator of about 2 percent (North American Bird Conservation Initiative 2014). Some grassland birds continue to decline, however, including the Eastern Meadowlark and the Bobolink which are native to eastern grasslands. In addition McCown's Longspur, the Chesnut-collared Longspur, and Sprague's Pipit which nest in the Western Great Plains are experiencing rapid declines which may be driven by large-scale agricultural conversion and over-grazing of their wintering grounds in the Chihuahuan Desert (North American Bird Conservation Initiative 2014).

Wetlands and Wetland Birds

Wetlands are considered to be one of the most biologically diverse ecosystems. Wetlands provide food, habitat and breeding grounds for a diverse number of plants and animals. Wetlands are important habitat for birds—of the 1,900 birds that breed in North America, 138 are wetland dependent (USGS n.d.). At the time of European settlement, the United States had approximately 221 million acres of wetlands. By 1997, over 50 percent of wetland acres had been lost, with an estimated 105.5 million acres of wetland remaining (Meals 2004). Most early wetland conversion was done for agricultural purposes, although some converted land was later used for urban development. An estimated 87 percent of the wetland losses from the mid-1950's to the mid-1970's were due to agricultural conversion (Meals 2004). U.S. agricultural policy during the majority of the twentieth century actively encouraged drainage of wetlands for agricultural production. For example, the Agricultural Conservation Program was established in 1940 to provide technical assistance and financial aid for landowners to drain wetlands on their property. This program alone was responsible for the drainage of nearly 57 million acres of wetlands over a 40-year period (Meals 2004).

Figure 4-2 Average annual net loss and gain estimates for the conterminous United States, 1954 to 2009



Source; Dahl 2014

Federal policy changes such as the Clean Water Act and State wetland laws began to sharply reduce wetland conversions beginning in the mid-1970s. The Swampbuster provisions of the 1985 Food Security Act (which removed incentives for draining wetlands), more rigorous permitting, additional State wetland regulation, and falling agricultural prices further reduced wetland conversion rates in the 1980s (Meals 2004). Between 1985 and 1997, loss of wetlands to agricultural uses was cut from 235,000 acres per year before 1985 to 27,000 acres per year from 1992 through 1997 (USDA NRCS N.d. "Wetland Conservation Provisions".).

Between 1998 and 2004, largely as a result of the "no net loss of wetlands" policy adopted in 1989, the United States saw a net gain of 32,000 wetland acres (See figure 4-2). Over this period there was a gain of 70,770 acres of restored wetlands on agricultural areas (Box 4-3)—which helped to offset some wetland losses as a result of urban and rural development (Dahl 2006). Between 2004 and 2009 there was a slight net loss of wetlands, mostly as a result of silviculture and urban/rural development. Again, wetland acres on agricultural lands increased by over 100, 000 acres during this time period (Dahl 2014).

As a result recent stabilizing trends in wetland losses coupled with active wetland restoration efforts, the United States has begun to see positive trends in populations of wetland-depend birds. The following analysis of trends for wetland-dependent birds is drawn from The State of the Birds 2014 (North American Bird Conservation Initiative 2014).

> "The inland wetlands indicator for 87 obligate freshwater breeding birds shows strong growth, with a more than 40 percent gain since 1968. These gains among wetland birds are the continuing legacy of important legislation such as the Clean Water Act and the Farm Bill's conservation provisions. According to USFWS breeding duck data, Mallards are 42 percent above their long-term population average. They are just one of several growing waterfowl populations that benefit from dedicated conservation efforts and funding. Federally protected wetlands (such as National Wildlife Refuges), state and local wildlife management areas, and Wetland Reserve Program projects on private lands conserve more than 10 million acres of waterfowl habitat along the four flyways. Nevertheless, more than 17 million acres of wetlands have been lost since the 1950s. Some wetland bird populations are declining in regions where significant wetlands loss continues. Long-term declines of wetland-dependent birds are most apparent in southeastern marsh species such as Mottled Duck, King Rail, and Purple Gallinule, as well as species dependent on ephemeral prairie wetlands in the Prairie Pothole Region of the Upper Midwest including Black Tern, Le Conte's Sparrow, and Northern Pintail."

Box 4.3 Farmers Create Wetland Habitat for Migratory Birds

While agriculture is a significant threat to biodiversity, in many cases it holds the key to preserving and restoring populations of our nation's at risk species. Unlike land conversion to urban areas, when land is converted to agricultural uses it maintains open space and vegetative cover that can provide food, habitat and migratory corridors to wildlife if managed appropriately. As the growing risks to our nation's biodiversity have come to be better understood, agricultural practices have begun to change in ways that are more symbiotic with the needs of some of the most at risk species.

For example, in California where it was once common to burn rice fields after the growing season, this practice is nearly extinct. Instead, many farmers now allow their fields to flood in the winter, providing 275,000 acres of surrogate wetlands and open space for 230 species along the Pacific Flyway, many of which are at risk, threatened or endangered (Cline 2005). This is especially important as 95 percent of California's traditional wetlands are gone (California Rice Commission 2015). As a result of winter flooding practices, populations have begun to increase for many of these species, and the number of ducks has doubled.

Similarly, in states along the Gulf coast and the lower Mississippi River, the USDA's Natural Resources Conservation Service (NRCS) provided funding for farmers to provide habitat for wetland-dependent migratory and in-land birds away from shore areas impacted by the 2010 Deepwater Horizon oil spill. As a result, 470,000 acres were enrolled. Wetland habitat was created through flooded rice fields, actively managed wetlands on agricultural lands and idled catfish ponds (Kaminski et al. 2014).

<u>The Prairie Pothole Region</u>

The Prairie Pothole Region, known for its ephemeral prairie wetlands, once covered about 16 to 18 percent of the landscape in the tall-grass and mixed grass prairie regions in the states of North Dakota, South Dakota, Minnesota and Iowa (See Table 4-1) (Dahl 2014). The Prairie Pothole Region is home to more than 50 percent of North American migratory waterfowl. Waterfowl breeding here include pintail, gadwall, blue-winged teal, shoveler, canvasback and redhead. Many other migratory birds—such as the snow goose, lesser scaup and wigeon—pass through the region on their way to or from the Arctic and other northern breeding grounds. Other important birds that rely on prairie wetlands include grassland birds such as the bobolink, sedge wren, Sprague's pipit, Baird's sparrow, and the increasingly rare grasshopper sparrow; 40 species of breeding waterbirds, such as American white pelicans, rails and herons; and shorebirds such as the piping plover, American avocet and Wilson's phalarope are among the shorebirds that breed in the prairie potholes region

(NWF). Other shorebirds such as the hudsonian godwit, American golden-Plover, white-rumped sandpiper and buff-breasted sandpiper pass through the potholes during their migration.

Over the past century, prairie wetlands and have been extensively drained and in some areas only isolated tracts of wetland habitat remain. Drainage for agriculture during the years preceding the 1980s was pervasive as tile and open-ditch drains eliminated large numbers of wetland basins and converted lands to crop production (Dahl 2014). Today, only 35 to 40 percent of regions original prairie pothole wetlands remain (Dahl 2014).

In 1986 the CRP was established. Over time up to 8.5 million acres of marginal cropland were enrolled in conservation covers, including 1.7 million acres of wetland and wetland buffers. Multiple studies of the CRP in the Prairie Pothole Region found the CRP had profound benefits for waterfowl and grassland birds. Reynolds, et.al (2007) estimated that between 1992 and 2004 2 million additional ducks were recruited annually. Drum et al. (2015) estimated that even with land leaving the CRP, 1.5 million ducks were recruited each year between 2007 and 2011. Estimates of the benefits from grassland birds have also been made. Studies can be found at http://www.fsa.usda.gov/programs-and-services/economic-and-policy-analysis/natural-resources-analysis/index

Table 4-1. Historic extent and trends of wetlands in the Prairie Pothole Region of the United States. Estimates from circa 1850 to the mid-1980s.

State	*Estimated Wetland Area (acres) Circa 1850*	*Estimated Wetland Area (acres) Circa 1980s*	*Change (percent)*	*References*
North Dakota	4.9 million	2.5 million	-49%	NRCS, wet soils of North Dakota (drained and undrained) unpublished; Dahl 1990.
South Dakota	2.7 million	2.1 million	-32%	NRCS, Huron, SD, unpublished data; Johnson *et al*. 1997
Minnesota	7 million	1.4 million	-80%	Redelfs 1980
Iowa	3.4 million	30,000 – 35,000	-90%	Bishop *et al.* 1998; Bishop 2006; Miller *et al.* 2009
Montana		—	—	—
Prairie Pothole Region	16.6 – 17 million	6 million	-60 to 65%	—

Source: Dahl 2014

In recent years, conversion of wetlands in the Prairie Pothole Region has slowed considerably (see Table 4-2), yet recent expansion of corn and soybean production in the Prairie Pothole Region continues to put pressure on wetlands. Several factors are driving the expansion and intensity of crop production, including commodity prices, warming weather patterns, and improved crop varieties that allow for the growing of more corn and soybeans (USDA NRCS 2014). These drivers create short-term incentives to convert existing grasslands—both native prairie or expiring Conservation Reserve Program (CRP) acreage—and some wetlands to crop production (USDA NRCS 2014). In addition, there are several indirect threats that degrade wetland habitat in the region. For example, use of pesticides can lead to loss of invetebrate populations upon which many waterbirds feed, or in some cases can lead to direct mortality of birds (Niemuth 2005).

Table 4-2 Estimated area change for wetland and deepwater habitat types in the U.S. Prairie Pothole Region, 1997 to 2009. (The Coefficient of Variation [CV] for each estimate is given in parentheses.)

Habitat Type	*Area 1997 (acres)*	*Area 2009 (acres)*	*Change Area (acres)*	*Change as Percentage*
Wetlands*	6,501,688 (4.2)	6,427,350 (4.3)	-74,340 (58.2)	-1.1%
Deep Water (lakes & rivers)	1,785,351 (12.3)	1,843,222 (12)	57,871 (33.6)	3.2%
Total Wetland & Deepwater	8,287,039	8,270,572	-16,467	-0.2%

*The wetland habitat type includes shrub wetlands, emergent wetlands (including emergent and farmed wetland categories), forested wetlands, and open water wetlands.
Source: Dahl 2014

To stem the tide of wetland conversion in the Prairie Pothole Region, NRCS recently launched the Prairie Pothole Wetland and Grassland Retention Project which will provide farmers and ranchers various financial and technical options to consider before they convert grasslands or wetlands to cropland. These options will provide farmers and ranchers with economically viable alternatives to protect their grasslands and wetlands (USDA NRCS 2014). The Prairie Pothole Wetland and Grassland Retention Project includes five elements:

> *Targeted EQIP funding*. EQIP funding will be targeted to improve management of grazing land and provide wildlife habitat. Up to $30 million over 3 years will be allocated to the Prairie Pothole Region with a goal of improving more than 45,000 acres of grazing land and more than 120,000 acres of wetlands and wildlife habitat.

> *Carbon credits for avoided conversion.* NRCS will work with private partners (e.g., Ducks Unlimited), to establish a carbon crediting protocol for avoided conversion of grassland with the idea that carbon payments will provide additional incentives for conservation.

> *Continuation of the North Central Wetland Conservation Initiative.* NRCS will devote $3 million in technical assistance to help streamline the wetland determinations process and reduce backlog in the program.

> *Agricultural wetland mitigation banking.* NRCS will develop wetland mitigation banks as a way to facilitate producer compliance with Wetland Conservation Compliance (WCC) provisions.

> *Water Bank Program.* The WBP provides annual payments to producers in exchange for

conserving and protecting wetlands on adjacent lands that might otherwise be used for crop production or other activities that require drainage

4.3 Pollinators

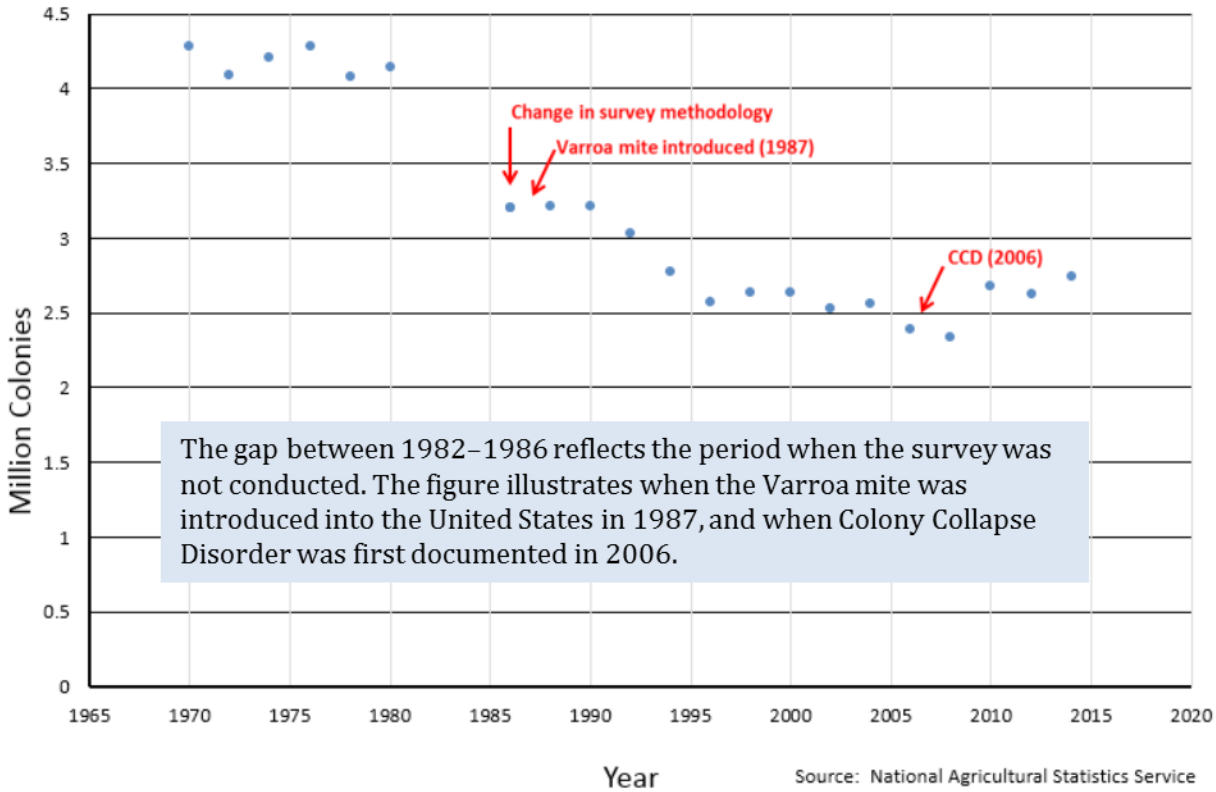
On May 19, 2015, the U.S. released the "National Strategy to Promote the Health of Honey Bees and Other Pollinators" (Pollinator Health Task Force 2015). The report identifies pollinator trends, for bees and monarch butterflies especially, and prepares a national strategy for improving pollinator habitat and reducing stressors. The following is excerpted from that report.

Pollinator health is a crucial component of managed and natural landscapes. Thriving pollinator populations promote healthy food systems and healthy ecosystems. The attributed value of crops that are directly dependent on insect pollination was estimated at $15 billion in 2009 in the United States (Calderone 2012). Recently, some pollinator populations have experienced notable declines, due to changes in habitat size and structure, pests and pathogens, pesticides and toxins present in the environment, and nutritional quality of forage, among other factors.

Domestic Losses of Honey Bees

Honey bees, the most recognizable pollinators of hundreds of economically and ecologically important crops and plants in North America, are an introduced insect, brought to the United States in the 1620's by early settlers. Approximately 2,000-3,000 commercial U.S. beekeepers manage their bee colonies as livestock, traveling across the country with their bees to service pollination contracts with U.S. farmers and to support honey production (Calderone 2012). Honey bees have been in serious decline for more than three decades in the United States, as noted in the National Academy of Sciences report Status of Pollinators in North America (National Research Council 2007). Declines in the number of managed honey bee colonies used in honey production have been documented by the USDA's National Agricultural Statistics Service (USDA NASS 2015). Starting in the 1940's when there were approximately 5.7 million colonies in the United States, the number of managed colonies used in honey production has declined to approximately 2.74 million colonies today (Figure 4-3).

Figure 4-3 Numbers (in millions) of managed honey bee colonies in the United States used for honey production

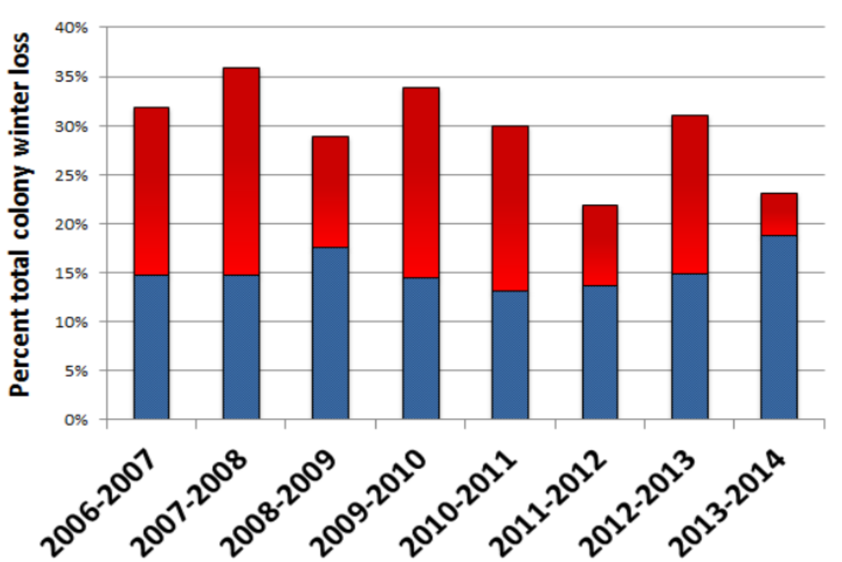


Sharp colony declines were seen following the introduction in 1987 of an external parasitic mite (*Varroa destructor*) that feeds on honey bee hemolymph (blood), and again around 2006 with the first reports of a condition referred to as Colony Collapse Disorder (CCD). Colonies diagnosed with CCD exhibit a rapid loss of adult worker bees, have few or no dead bees present in the colony, have excess brood and a small cluster of bees remaining with the queen bee, and have low Varroa mite and Nosema (fungal disease) levels. Colonies exhibiting CCD have insufficient numbers of bees to maintain the colony (*e.g.*, rearing and maintenance of developing young, food collection, and hygiene) and these colonies eventually die. Although CCD has become synonymous with all honey bee colony declines, the actual proportion of losses directly attributable to CCD is low and has been decreasing over the past four years, based on beekeeper winter loss surveys conducted by the Bee Informed Partnership, supported by the USDA (Steinhauer *et al*. 2013).

Although Figure 4-3 indicates that the number of managed honey bee colonies has been relatively consistent since 1996, the level of effort by the beekeeping industry to maintain these numbers has increased. Annual surveys of beekeepers since 2006 indicate overwintering losses alone averaging around 31 percent (Figure 4-4), which far exceeds the 15-17 percent overwintering loss rate that commercial beekeepers have indicated is an economically sustainable average (Steinhauer *et al.* 2014). When overwintering losses are coupled with colony losses occurring during other times of the year, annual losses can be considerably higher (Steinhauer *et al.* 2013). This is particularly notable in the 2014-15 preliminary report of 27.4 percent total summer colony losses in the Bee

Informed Partnership survey of a subset of national beekeepers, for total annual losses of 42.1 percent of colonies (Steinhauer et al. 2015).

Figure 4-4 Annual overwintering losses of managed honey bee colonies



Represents losses between October 1 and April 1 (red bars), and self-declared acceptable mortality level from participant beekeepers (blue bars). *Source: Bee Informed Partnership 2014 (http://beeinformed.org/2014/05/colony-loss-2013-2014/)*

Meeting the growing demand for pollination services in agricultural production has become increasingly difficult. Beekeepers transport bees long distances to pollinate crops such as apples, blueberries, cherries, squash, and, particularly, almonds. Approximately 60–75 percent of all U.S. commercial honey bee colonies are required in almond orchards early each spring to fulfill pollination contracts (Bond *et al*. 2014). When overwintering colony losses are high, beekeepers must compensate for these losses by "splitting" one colony into two, supplying the second colony with a new queen bee and supplemental food in order to quickly build up colony strength to fulfill almond pollination contracts. This practice results in increased maintenance costs to both the beekeeper and the orchard grower renting the hives, with hive rental fees for almond pollination rising from approximately $76 per hive in 2005 to over $150 per hive in 2009 (Bond *et al.* 2014).

Researchers studying CCD and other losses attributed to poor colony health have been unable to identify a single cause, and have concluded that losses of honey bee colonies are the result of a complex set of interacting stressors. In May 2013, the USDA and the EPA released a comprehensive scientific report on honey bee health (USDA 2012). The report synthesized the current state of knowledge regarding the primary factors that scientists believe have the greatest impact on honey bee health, including exposure to pesticides and other environmental toxins, poor nutrition due in part to decreased availability of high-quality/diverse forage, exposure to pests (*e.g.*, Varroa mites) and disease (viral, bacterial, and fungal), as well as bee biology, genetics, and breeding. The report's findings are similar to those of the report on the *Status of Pollinators in North America* (NRC 2007), which examined wild (both native and introduced species) pollinators as well as honey bees.

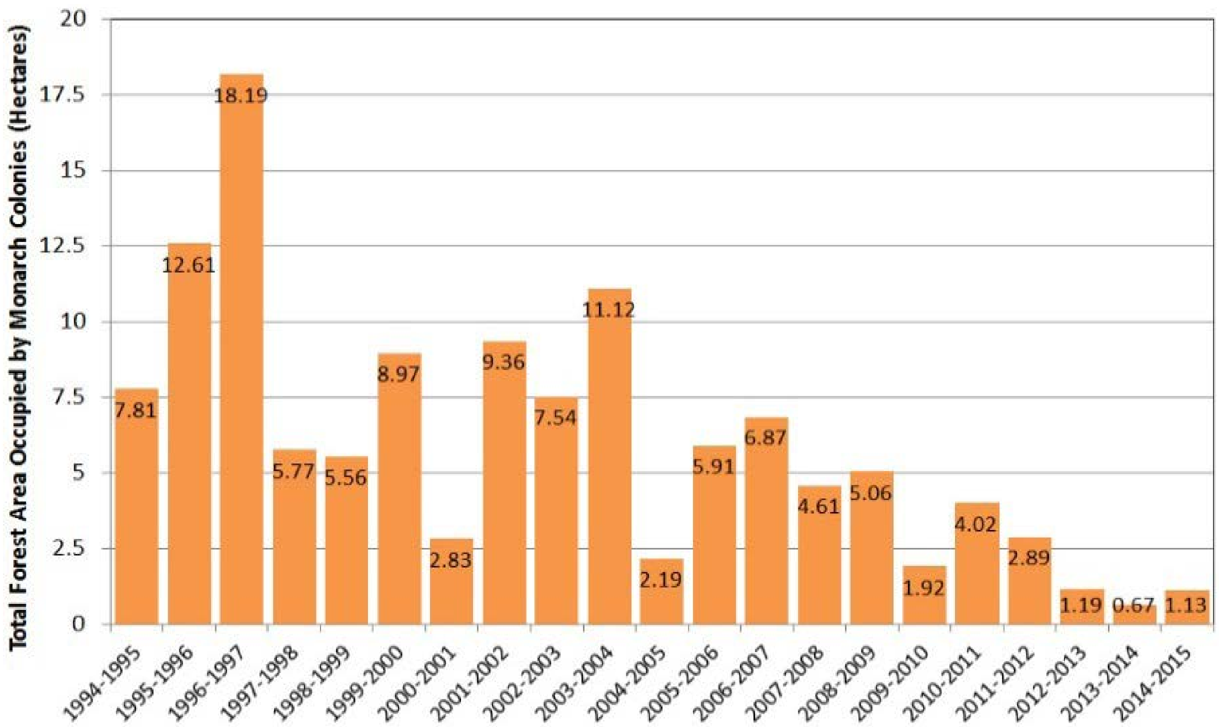
Domestic Losses of Other Pollinators

In addition to honey bees, there are over 4,000 wild bee species in the United States (Moisset and Buchmann 2011). Population declines in the United States have been documented for some populations of non-managed pollinators, for example, the two-formed bumble bee (*Bombus bifarius*) (Spivak *et al.* 2011; Cameron *et al.* 2011), but little is known about trends for populations of non-managed bees that comprise the majority of pollinators (Winfree *et al.* 2007; Lebuhn *et al.* 2013). Some bumble bee populations are suffering from introduced pests and diseases, potentially transferred from managed bees (Colla *et al.* 2006; McMahon *et al.* 2015). Non-*Apis* bees, butterflies, bats, and other managed or wild pollinators are also impacted by habitat loss and degradation, and there is strong evidence that, for some species, habitat loss has led to population declines (NRC 2007; Potts *et al.* 2010). All pollinators must also cope with the effects of climate change, which may have direct impacts on behavior and physiology, and indirect impacts through floral resource availability and phenology, as well as changing dynamics of pests, pathogens, predators, and competitors (Potts *et al.* 2010; Le Conte and Navajas 2008).

As with honey bees and other managed or wild bee pollinators, there have been marked (~90 percent) declines in monarch butterfly (*Danaus plexippus*) populations over the past several years (Figure 4-5). In February 2014, President Obama committed to work together with Canadian Prime Minister Stephen Harper and Mexican President Enrique Peña Nieto to ensure the conservation of the monarch butterfly. Much of a monarch butterfly's life is spent completing part of an annual cycle of migration over the course of multiple generations, either across North America between Canada into Mexico (Eastern migration), or between the Rocky Mountains and groves in California (Western migration). The iconic Eastern migration, in particular, has become less successful for many monarchs because of losses in nectar-producing plants that provide sustenance to the adult butterflies, as well as in the availability of milkweed plants on which developing monarch larvae feed exclusively. Primary stressors of concern for the Eastern population include loss of milkweed breeding habitat in corn and soybean production, loss of breeding habitat due to land conversion, illegal logging and deforestation at overwintering sites, and extreme weather conditions. Natural enemies such as diseases, predators, and parasites, and use of insecticides in agricultural, urban, and suburban areas are also of concern.

Determining the current status of insect pollinator communities, documenting shifts in distribution and abundance of various species, and refining methodologies for documenting changes remain important areas of research (Lebuhn *et al.* 2013), along with developing taxonomic capacity to identify the thousands of North American bee species. Additional research is also needed on the value of pollinators in natural systems, which is much more difficult to discern than for managed honey bees. The economic value of managed non-*Apis* bees, *e.g.*, blue orchard bees (*Osmia lignaria*), alfalfa leafcutting bees (*Megachile rotundata*), bumble bees (*Bombus spp.*), etc., has not been well-quantified, despite the fact that these species are highly effective crop pollinators. Wild, native bees also provide the majority of pollination that helps maintain natural plant communities which contribute to a variety of valuable ecosystem services, including carbon sequestration, water filtration, and erosion control (NRC 2007). Simultaneous declines in wild and managed pollinator populations globally, with noted decreases in honey bees, bumble bees, and monarch butterflies, have brought into focus the importance of pollinator conservation (Cameron *et al.* 2011; NRC 2007; Pettis and Delaplane 2010; vanEngelsdorp *et al.* 2009).

Figure 4-5 Area of forest occupied by colonies of hibernating monarch butterflies in Mexico from 1994 –2015



Source: The Monarch Joint Venture

data from 1994-2003 were collected by personnel of the Monarch Butterfly Biosphere Reserve (MBBR) of the National Commission of Protected Natural Areas (CONANP) in Mexico. Data from 2004-2015 were collected by the WWF-Telcel Alliance, in coordination with the Directorate of the MBBR. 2000-01 population number as reported by Garcia-Serrano et. al (The Monarch Butterfly: Biology and Conservation, 2004)

The recently-released National Pollinator Health Strategy is aimed at addressing pollinator declines through a series of activities, including research, education and outreach, an evaluation of neonicotinoid pesticides, and improving pollinator habitat (Box 4-4). In fact, progress has already been made towards increasing and improving pollinator habitat through existing federal Farm Bill programs administered by USDA, including the Conservation Reserve Program (CRP), the Conservation Stewardship Program (CSP), and the Environmental Quality Incentives Program (EQIP):

> *Conservation Reserve Program (CRP)* In June of 2014, the USDA announced the availability of $8 million in CRP for mid-contract management incentives for Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin farmers and ranchers who establish new habitats for declining honey bee populations on their existing CRP acres. These five states are home for more than half of the commercially managed honey bees during the summer and offer a

large area of potential habitat. In 2012, USDA reserved 100,000 acres of CRP land for pollinator habitat, and, to date, about 35 percent of those acres have been enrolled in the program, with a majority of enrolled acres coming into CRP during the past year. Three-quarters of CRP pollinator habitat enrollments are in Iowa and Illinois. Outside of the special CRP pollinator habitat initiative, USDA estimates an additional 98,000 acres of CRP land are pollinator habitat acres, with Texas and Colorado the leading states in that category. The new strategy will explore ways to increase those CRP pollinator acres.

Conservation Stewardship Program (CSP) The CSP program, which provides long-term stewardship payment for advanced conservation systems, has nearly 3,000 CSP contract holders that have selected enhancements that establish pollinator habitat in non-cropped areas on their lands. Through these enhancements, participants seeded over 11,000 acres of nectar and pollen producing plants in field borders, vegetative barriers, buffer strips, and waterways, providing increased diversity for pollinator habitat. Additional CSP enhancements beyond the ones targeted to habitat also continue to support producers in reducing pesticide application and providing a critical food supply for pollinators and beneficial insects.

Environmental Quality Incentives Program (EQIP) Through EQIP, USDA provided $3 million in FY 2014 and an additional $4 million in FY 2015 for technical and financial assistance for interested farmers and ranchers to improve bee health through working lands. This funding is available for conservation practices that increase habitat area and safe food sources for honey bees.

USDA's Farm Service Agency (FSA) and NRCS are cooperating with the U.S. Geological Service (USGS) to monitor and assess the effectiveness of these conservation efforts. USGS is identifying the plants honey bees are visiting and working with USDA's Agricultural Research Service (ARS) to track the hives and assess the effect of the conservation pollinator plantings on hive health and survival.

Box 4-4 Pollinator Health Strategy

A Presidential Memorandum issued in 2014 (The White House 2014) called for the formation of an inter-agency task force to promote the health of honey bees and other pollinators. In May, 2015, the Task Force released the "National Pollinator Health Strategy" that incorporates research and development, outreach, and public-private partnerships. In addition, building on agency-specific actions, either identified in the Presidential Memorandum or through enhanced actions by individual agencies, the Strategy seeks to identify opportunities and initiatives for addressing both short-term and long-term habitat improvement that will benefit overall pollinator health. While the focus of the Strategy is on improving pollinator health, many of the recommendations identified in the Strategy will also have collateral benefits in improving ecosystems more broadly, through encouraging development and maintenance of native habitats and more ecologically sustainable land management practices. This is especially true for efforts to protect the monarch butterfly, which is a minor pollinator but a major indicator of biodiversity and ecosystem health.

The Strategy includes three outcome metrics: (1) returning honey bee colony health to acceptable levels (approximately 15% overwintering loss, a level from which beekeepers are capable of successfully dividing surviving healthy colonies to remain economically viable); (2) increasing monarch butterfly populations to historic averages to ensure successful continuation of annual migrations; and (3) increasing and maintaining cumulative pollinator habitat acreage in critical regions of the country.

In order to achieve these goals, the strategy outlines an approach that includes the following four components:

- Implementing the Pollinator Research Action Plan. Research will focus on population trends among pollinators, identifying pollinator friendly seed mixes; developing best practices for limiting pollinator exposure to pesticides; and creating strategies for targeted restoration activities.
- Expanding education and outreach. Outreach strategies will include developing outreach materials for educators, corporations and the general public and will encourage individual activities that can help improve pollinator habitat.
- Leveraging public-private partnerships. Federal agencies will work through public partnerships (e.g. seed companies, farm and forestry organization, NGOs, etc.) to maximize impact of its pollinator health strategy.
- Improving pollinator habitat.
- Protecting pollinators from exposure to pesticides

4.4 Soil health

Soil biodiversity refers to the diversity organisms living within the soil. These organisms are necessary for healthy soils. In turn, healthy soils provide a variety of ecosystem services including water regulation, nutrient cycling, filtering and buffering potential pollutants, providing physical stability and support to plant roots and human structures, and sustaining a variety of plant and animal life (Tugel et al. 2000)

The soil food web is comprised of bacteria, fungi, protozoa, nematodes, and anthropods, and is sustained by organic matter which provides necessary food and habitat for these organisms. The number and composition of organisms in the soil food web is dependent upon both type of soil and availability of suitable food and habitat. Each species and group exists where they can find appropriate space, nutrients, and moisture. They occur wherever organic matter occurs - mostly in the top few inches of soil (Tugel *et al.* 2000). Figure 4-6 shows typical numbers of these organisms in three types of soils, agricultural, prairie and forest.

Figure 4-6. Typical numbers of soil organisms in healthy ecosystems.

Typical Numbers of Soil Organisms in Healthy Ecosystems

		Agricultural Soils	Prairie Soils	Forest Soils
Bacteria	Per teaspoon of soil (one gram dry)	100 million to 1 billion.	100 million to 1 billion.	100 million to 1 billion.
Fungi	Per teaspoon of soil (one gram dry)	Several yards. (Dominated by vesicular-arbuscular mycorrhizal (VAM) fungi).	Tens to hundreds of yards. (Dominated by vesicular-arbuscular mycorrhizal (VAM) fungi).	Several hundred yards in deciduous forests. One to forty miles in coniferous forests (dominated by ectomycorrhizal fungi).
Protozoa	Per teaspoon of soil (one gram dry)	Several thousand flagellates and amoebae, one hundred to several hundred ciliates.	Several thousand flagellates and amoebae, one hundred to several hundred ciliates.	Several hundred thousand amoebae, fewer flagellates.
Nematodes	Per teaspoon of soil (one gram dry)	Ten to twenty bacterial-feeders. A few fungal-feeders. Few predatory nematodes.	Tens to several hundred.	Several hundred bacterial- and fungal-feeders. Many predatory nematodes.
Arthropods	Per square foot	Up to one hundred.	Five hundred to two thousand.	Ten to twenty-five thousand. Many more species than in agricultural soils.
Earthworms	Per square foot	Five to thirty. More in soils with high organic matter.	Ten to fifty. Arid or semi-arid areas may have none.	Ten to fifty in deciduous woodlands. Very few in coniferous forests.

Source: NRCS

Soil organic matter is critical for maintaining a healthy soil ecosystem that can support crop and pasture systems. Soil organic matter is best maintained in the soil by disturbing the soil as little as possible, growing as many different species of plants as practical, keeping living plants in the soil as often as possible and keeping soil covered (Tugel *et al*. 2000).

Degradation of soil and loss of soil health impacts these important microorganisms. Soil is degraded as a result of land conversion and land management practices. Degraded soil has less soil organic matter and is more susceptible to erosion and compaction as a result of reduced soil aggregation. Soils are degraded as a result of intensive tillage practices, removal of residues, decreased crop/plant diversity, bare soils and compaction as a result of heavy grazing or farm equipment (Tugel *et al.* 2000).

Issues of soil health first became prominent in the United States in the 1930's during the Dust Bowl, where severe drought coupled with high winds led to unprecedented soil erosion in the Plains area of the United States and Canada. The first nationwide assessment of soil conditions took place in

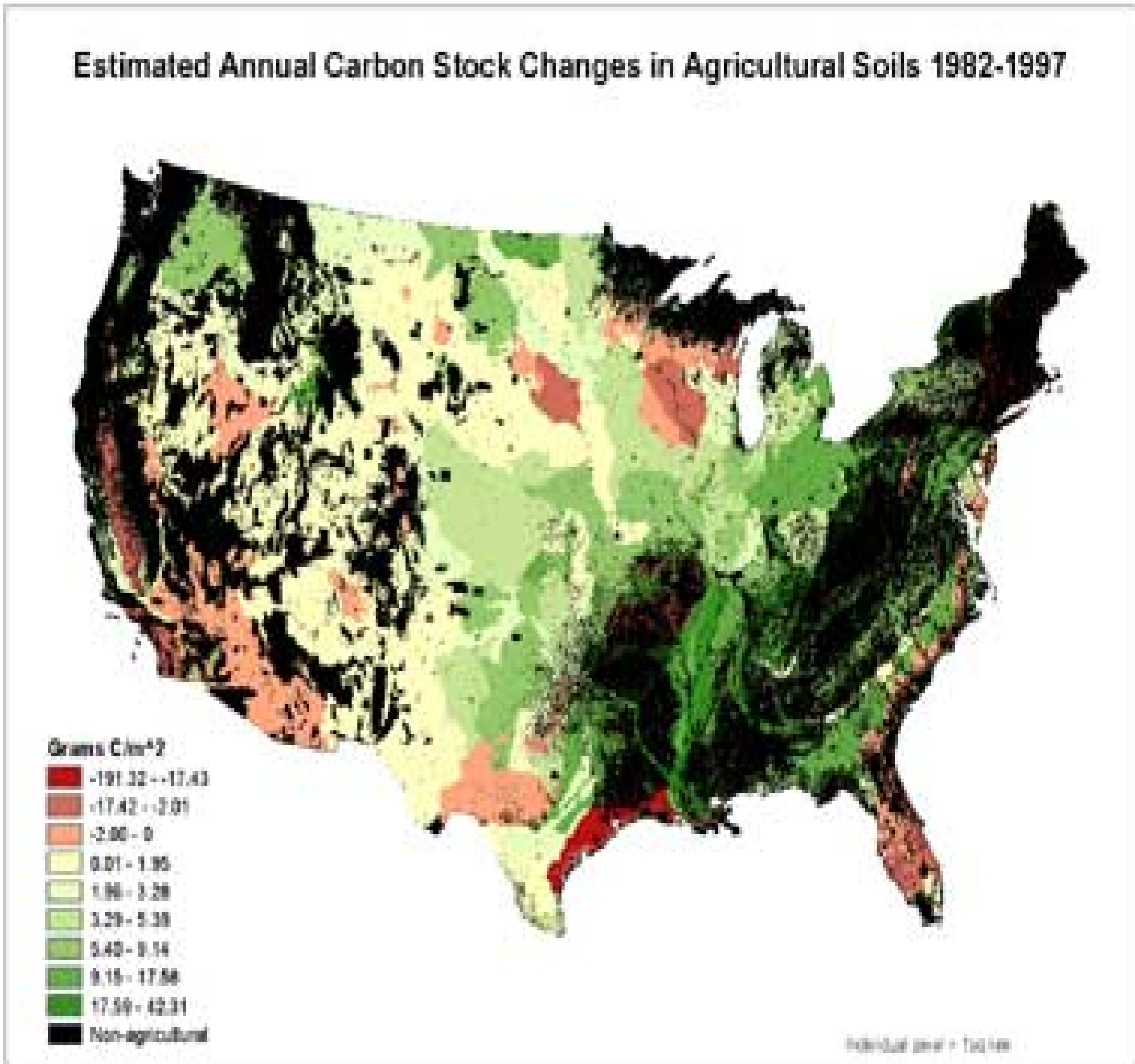
1934 when 115 soil-erosion specialists fanned across the country over a 2-months period to complete a survey of nearly 2 billion acres (Schmude 1988). Findings indicated that nearly half of the surveyed acres were affected by water erosion and one-sixth by wind erosion. In addition, nutrients lost along with the soil particles negatively impacted soil health (SCS 1935). Erosion of soil by wind and water affects health and water quality as well as plant vigor and wildlife biodiversity.

Soil degradation was the original factor that motivated the United States conservation policy and remains an important parameter used to measure policy process. The National Resource Inventory (NRI) has been collected every five years since 1977 to assess the state of the land. Through NRI data and other studies researchers are able to assess ongoing trends in conservation practices as a proxy for soil health, with a focus on soil carbon, soil erosion, adoption of reduced tillage practices, adoption of crop rotations, and adoption of cover crops. Adoption of these conservation practices of shows positive trends, an indication that soil health in the United States might be improving on lands adopting these practices, which could have positive impacts on soil biodiversity.

<u>Soil Carbon</u>

Soil carbon is the carbon that is stored in soil organic matter (SOM). Organic carbon enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. SOM is the organic fraction of soil exclusive of nondecomposed plant and animal residues. Recent studies have estimated the change in soil carbon stocks over time using NASA remote sensing technologies. Results show that changes in land use and agricultural management (primarily CRP and some conservation tillage) have resulted in a net gain of 17.1 MMT (million metric tons) of carbon in U.S. agricultural soils over the period from 1982 to 1997 (Figure 4-6)(Eve et al. 2002).

Figure 4-6 Estimated annual carbon stock changes in agricultural soils 1982-1997



Soil Erosion

The NRI data show that wind and water (sheet and rill) erosion have decreased between 1982 and 2010 (figures 4.8 and 4.9). Soil erosion on cropland decreased overall by 41 percent between 1982 and 2010. Water (sheet and rill) erosion declined from 1.67 billion tons per year to 982 million tons per year, and erosion due to wind decreased from 1.38 billion to 740 million tons per year. The estimate of the change in erosion from 2007 to 2010 was not statistically significant from zero.

Erosion has not been controlled everywhere, however. As figure 4-7 demonstrates, soil erosion remains above tolerable soil loss levels in many areas. Tolerable soil loss is defined as the maximum average soil loss that can occur in a given area without compromising current and future levels of production.

Figure 4-7 Erosion exceeding the soil loss tolerance rate in 2010

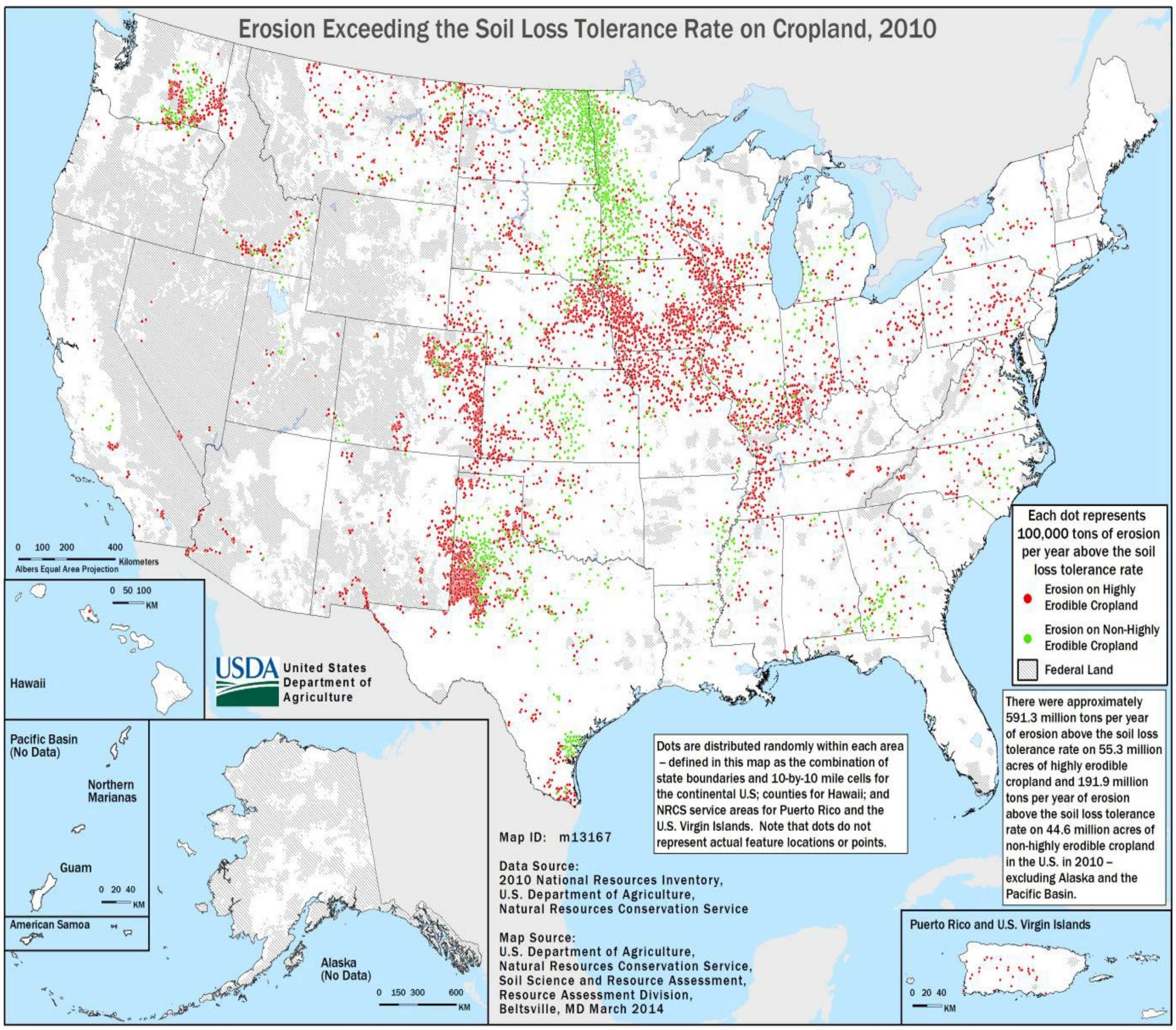
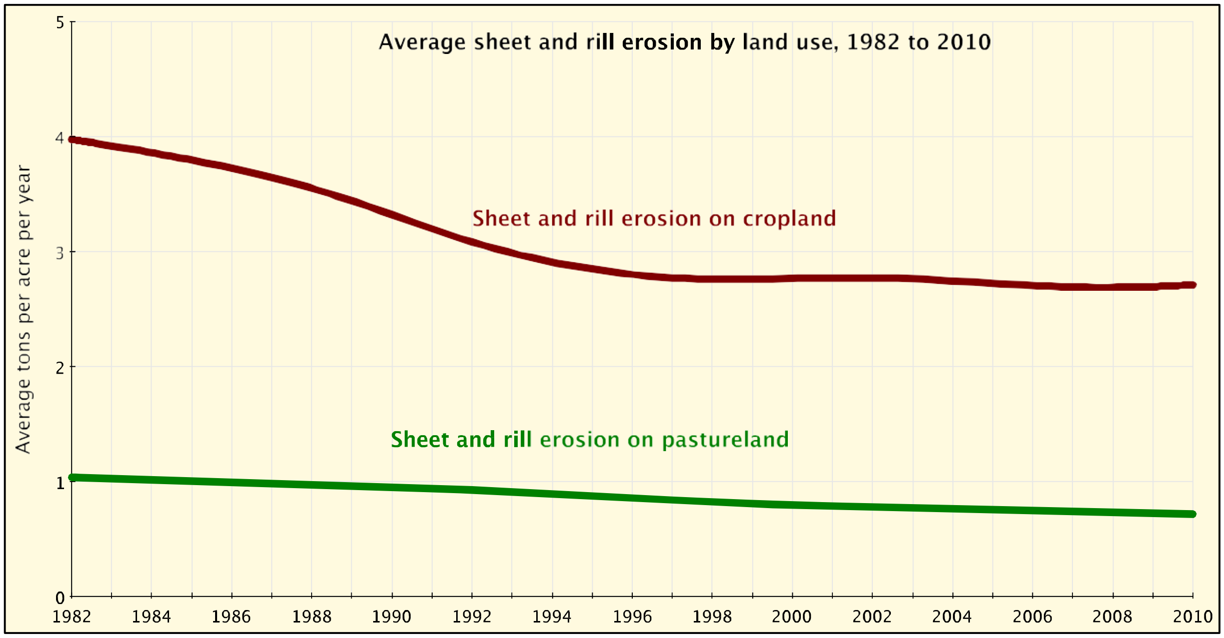
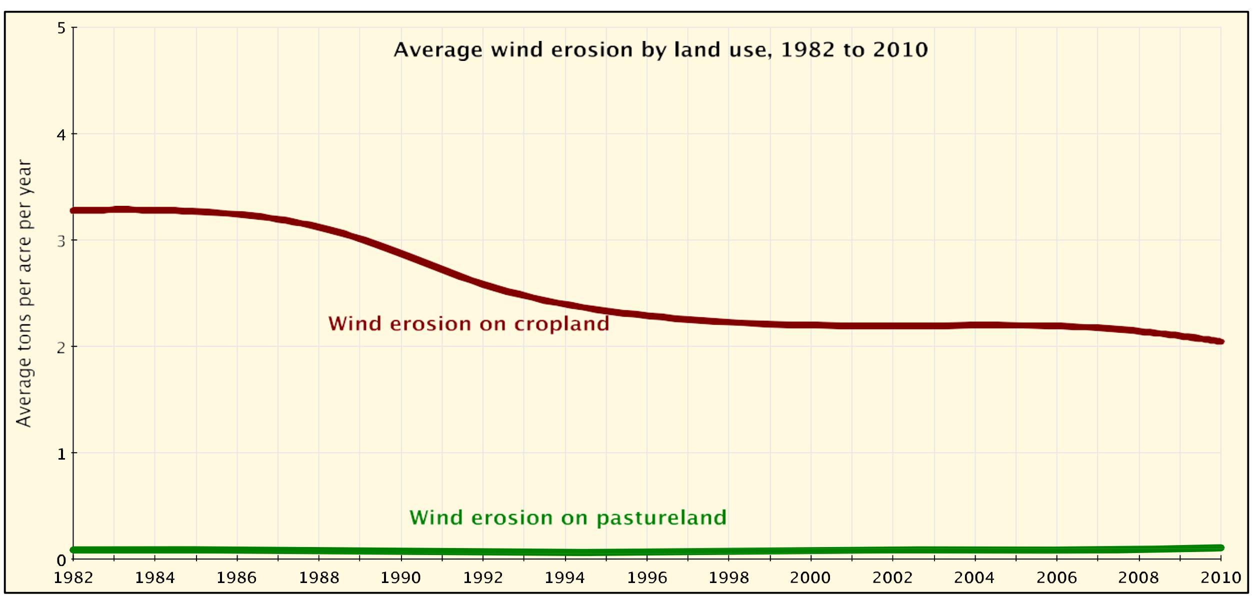


Figure 4-8. Average sheet and rill erosion on non-Federal lands in the United States from 1982 to 2010



Source: U.S. Department of Agriculture. 2013. Summary Report: 2010 National Resources Inventory, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1167354.pdf

Figure 4-9 Average wind erosion on non-Federal lands in the United States from 1982 to 2010



Source: U.S. Department of Agriculture. 2013. Summary Report: 2010 National Resources Inventory, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1167354.pdf

5. State of Use of Biodiversity for Food and Agriculture

At a basic level, all agricultural production uses biodiversity. This section focuses in on five aspects associated with the direct use of biodiversity and ecosystem services: wild food consumption; wild relatives for crop breeding, integrated pest management, organic agriculture, and agro-forestry.

5.1 Wild foods

Wild foods in the United States are harvested for commercial and personal use. Capture fisheries constitute one of the largest commercial wild food industries. Other commercial wild food industries include mushrooms, maple syrup, blueberries, ginseng, herbs, kelp, and seaweed (USDA 2011a). In addition to commercial uses, wild foods continue to be valuable in the diets of many populations in the United States. Diverse people in the United States, including urban, rural and Native American populations, forage, fish, and hunt wild foods, however there is very little data on the extent to which wild foods are utilized in the U.S. diet. Some data that can be used as indicators of the use of wild foods include participation in hunting and fishing, the value of capture fisheries, and the value of various other commercial wild foods.

Wild foods were once a staple in the diets of early European Settlers and Native Americans, though dependence on these foods varied. Europeans as well as some Native American tribes in the eastern woodlands and southwest relied on agriculture for their nutritional needs while wild game, fish and foraged plants helped to supplement their diets. Native American tribes that did not practice agriculture—for example, those in the Great Plains, Pacific Northwest and Alaska—relied entirely on wild foods in their diet.

Traditional foods and dishes in addition to the activities of hunting and fishing were important social and cultural aspects of Native American life. Native peoples of the Pacific Northwest are often collectively referred to as the Salmon People, an indication of the great importance of salmon to their native culture and diets. The annual return of the salmon symbolized the continuous renewal of life. Traditional serving rituals started with fresh water, then salmon, deer or elk meat and edible roots, followed by huckleberries, chokecherries, and other berries. Prior to European settlement, it is estimated that salmon and other marine foods accounted for 90 percent of the protein consumed by the native peoples in the coastal areas of the Pacific Northwest (Garner & Parfitt 2006). Today, fishing remains the preferred livelihood for many tribal members (Columbia River Inter-Tribal Fish Commission n.d.).

Similarly, the American buffalo had social, cultural, spiritual, economic significance to the native tribes of the Great Plains. The American buffalo was used not only for food, but also for clothing, shelter, tools, and medicine. In addition to relying on buffalo, tribes would forage for wild foods like chokecherries and blueberries in the spring. During the summer they would also hunt and fish, smoking and drying meats to last the winter.

Today, wild foods in the U.S. diet have decreased significantly compared to 150 years ago; in fact, wild foods are rare or absent in many modern diets. Native American diets in particular have undergone radical transitions (Taylor 2005). Loss of traditional homelands, local hunting and fishing restrictions, and reduced availability of traditional game and plants required changes to traditional diets and agronomic practices and relegated traditional wild foods to peripheral status in the majority of Native American diets (Taylor 2005). Studies have found that the prevalence of wild game and other wild foods in Native American diets continues to decline with successive generations (Hunter 2005).

Nevertheless, hunting and fishing remain important cultural activities in the United States, in both native and non-native populations, and contribute to wild foods in the U.S. diet. In 2011, the U.S. Fish and Wildlife Service estimates that 14 percent of the U.S. population over the age of 16 (33.1 million people) participated in fishing (freshwater and marine); and an estimated 6 percent of the U.S. population over the age of 16 (13.7 million people) participated in hunting. Big game hunting engaged 11.6 million hunters, while 4.5 million hunters pursued small game, 2.6 million hunters pursued migratory birds; and 2.2 million hunters pursued other types of game such as raccoons and feral pigs. The most popular big game was deer (10.9 million hunters) followed by wild turkey, elk and bear. Popular small game included squirrel (1.7 million hunters), rabbit/hare (1.5 million hunters), pheasant (1.5 million hunters), quail (.8 million hunters) and grouse (.8 million hunters). Among those hunting migratory birds, 1.4 million hunted ducks, 1.3 million doves, and .8 million hunted geese. (All data from USFWS 2011.)

A study of the role of wild game in the diet of recreationists in South Carolina found that wild-caught fish and game was eaten nearly 8 or 10 times per month (Burger & Gochfeld 2002). The same study found that wild-caught fish and game (with the exception of deer) was consumed primarily by low-income minority populations (Burger & Gochfeld 2002). Another study in Louisiana found that wild game was consumed regularly by 47 percent of the survey respondents (Eriksen 2008). Of those study participants that consumed wild game, nearly half identified as Cajuns. Cajuns are an ethnic group living in southern Louisiana descended from French Canadians. Traditional Cajun cuisine focuses on local ingredients and wild game, with coastal Cajun communities also relying heavily on fish and shellfish. The Cajun community tends to be more economically disadvantaged and rural, living closer to swamps and wetlands where wild game is plentiful.

Wild food consumption in the United States is highest in the state of Alaska where subsistence (i.e., reliance on wild foods) is a way of life for many. Many Alaskans use wild plants and animals, especially fish, to put food on the table. Cultural factors in addition to the high cost of food and fuel in the rural areas contribute to a heavy reliance on wild foods. For Alaska Natives in particular, gathering, preparing, and sharing wild foods are integral to the history, culture, and health of individuals and communities (USDA 2011b). A study in Alaska found that communities, such as the Nikolai and Akiachak, consume approximately 100kg per capita of caribou and moose meat annually. The study estimates that 60 percent of rural Alaska households participate in hunting and a further 86 percent of rural Alaska households consume wild game (Titus et al. 2009).

<u>Nontimber Forest Products</u>
In the United States, many wild foods are foraged or harvested from forests. Nontimber forest products include wild plants and fungi that people gather and use for food, medicine, crafts, and spiritual, aesthetic, and utilitarian purposes. Some examples include:

The American matsutake mushroom. The matsutake can be found across the northern coniferous forest belt, distributed east-west across Canada, and temperate conifer dominated forests extending southward along the Appalachian, Rocky, Cascade, Sierra Nevada, and Pacific Coast mountain ranges (Hosford et al. 1997). This edible mushroom is one of many valued forest mushrooms harvested commercially, recreationally, and culturally across western North America (Amaranthus et al. 2000, Luoma et al. 2006, Anderson and Lake 2013, Garibay-Orijel et al. 2007).

Native Americans utilized American Matsutake for a variety of cultural culinary uses, many of which are still used today and are popular among tribal and other non-indigenous harvesters (Richard 1997, Anderson and Lake 2013). Many people in the Pacific Northwest and northern California harvest the mushrooms as food for personal consumption as well as for local seasonal commercial markets for fresh export (Amaranthus et al. 2000). While the matsutake is adaptable to many human and natural disturbances it does face some threats from urbanization, and forest management practices that reduce or eliminate habitat for host plant species.

Ramps. Ramps, or wild leeks, were prized by Native Americans and early European settlers who would eat these onions as the first green of the year. Harvesting of ramps for personal use continues today. Harvesting intensity increased with development of markets as entrepreneurs started selling ramps at roadside vegetable stands, farmers' markets, and even to local restaurants. In the late 1990s, the plant's popularity increased tremendously when culinary aficionados started promoting it.

Ramps are sensitive to environmental changes and stressors, brought on by forest management. These understory plants are especially sensitive to disturbances that change the characteristics of the forest overstory. Changes in soil moisture and temperature due to changes in forest stand dynamics, as well as climate variations could impact growth and maintenance of natural populations of ramps and other spring ephemerals.

The Evergreen huckleberry. The Evergreen huckleberry is an understory shrub associated with coastal forests of the Pacific Northwest and northern California. This huckleberry is harvested for food, floral arrangements, and medicine (Kerns et al. 2004, Hummer 2013). Native Americans utilized Evergreen huckleberry for a variety of cultural and culinary uses, many of which are still used today and are popular among tribal and other non-indigenous harvesters. Many people in the coastal Pacific Northwest and northern California harvest the berries as food for personal consumption as well as local commercial and value-added markets (e.g., jams, syrups, pies, floral arrangements, herbal medicines, landscaping) (Alderman 1979, Kerns et al. 2004). Commercial harvesting of the huckleberry fruit has been a regional enterprise for decades. In the 1950s, it was reported that typically over 500 tons of berries were harvested annually—in some years exceeding 1,000 tons (Beakey 1960: 1097). Harvest for personal and regionally local markets continues to be important for many rural communities, although data on production (i.e. sales and market value) levels is not widely available (Vasquez and Buttolph 2010).

> Threats to the Evergreen huckleberry include development and urbanization of natural and managed forest habitats that reduce and eliminate huckleberry dominated habitat. In addition, climate change related disturbances such as extreme weather and temperatures, drought and high severity fires affect growth and mortality of the huckleberry.

A study by the U.S. Forest Service investigated the use of nontimber forest products in Maine, a heavily forested state (USDA 2010b). They found that the study population, which includes Native Americans, utilized 55 different types of wild foods from forests, including blueberries, cranberries, chives, fiddlehead ferns, young dandelion leaves, and beaked hazelnuts. The United States lacks comprehensive data on the harvesting of nontimber forest products, though some regional data do exist for some wild foods that are harvested for commercial purposes. For example, some data are collected on the harvest of wild mushrooms in the Pacific Northwest where, in 1992, 825,000 pounds (374,140 kg) of American matsutake were harvested in Idaho, Oregon, and Washington (Alexander et al. 2002), with a mean commercial value of $8 per pound.

<u>Fish</u>

Commercial landings (edible and industrial) by U.S. fishermen at ports in the 50 states were 4.5 million metric tons valued at $5.5 billion in 2013. Finfish accounted for 87 percent of the total landings, but only 47 percent of the value. Commercial landings by U.S. fishermen at ports outside the 50 states provided an additional 252,061 metric tons valued at $549 million. Most of these landings consisted of tuna landed in American Samoa and other foreign ports. Important commercial species include: Alaska Pollack & other Pacific trawl fish, Anchovies, Halibut, Sea Herring, Mackerel, Menhaden, North Atlantic trawl fish (butterfish, cod, cust, flounder, haddock, hake, ocean perch, etc.), Pacific salmon, sablefish, tuna, clams, crabs, lobster, oysters, scallops, shrimp, and squid.

The 2013 U.S. marine recreational finfish harvest (fish kept or released dead) was estimated at 167 million fish weighing 239 million pounds (108,408 metric tons) (NOAA 2014b). Top recreational species (by weight) include striped bass, red drum, spotted seatrout, bluefish, yellowfin tuna, red snapper, dolphinfish, summer flounder, Spanish mackerel, and mullets. The 2013 recreational catch for all but summer flounder and mullets exceeded the commercial landings for these species (NOAA 2014b).

Catch totals for freshwater are not reported in most instances, though some states may collect this data for valued species. For example, Washington State reported that freshwater recreational catch for salmon totaled 587,982 fish in 2012. The most commonly sought freshwater fish include black bass, panfish, trout, catfish/bullhead, crappie, white bass and striped bass (USFWS 2011).

<u>Trends in wild food abundance</u>

Wild food sources in the United States face threats that are external (disease, climate change, land use change) and internal (overexploitation and unsustainable management). A study of population and harvest of game in the United States conducted by the U.S Forest Service found that, on average, small game harvests had declined by 49 percent between 1975 and 2000 (Flather et al. 2009). While this decrease may be attributable to several factors including changes in hunter preferences, changes in access to land, or changes in days hunted, it is also, at least in part, attributable to population declines. In particular, small game species associated with grassland habitats or agricultural systems (e.g. the northern bobwhite, sage grouse) show very little sign of long-term recovery (Flather et al. 2009). Grassland habitats are the most threatened ecosystem in North America with significant portions converted to agricultural or urban uses.

Salmon, a wild food of great importance to the Native American tribes of the Pacific Northwest, Alaska Natives, and commercial fisheries has also been impacted by alterations to their habitat. During their five year lifespan, salmon will migrate thousands of miles, from mountain streams to the Pacific Ocean and back again to spawn and die. Salmon are threatened by alternation of their stream habitat; water storage, withdrawal, conveyance, as well as water diversions for agriculture, flood control, domestic, and hydropower purposes have greatly reduced or eliminated historically accessible habitat and can directly contribute to fish death (NOAA 2014a). Modification of natural flow regimes have resulted in increased water temperatures, changes in fish community structures, depleted flows necessary for migration, spawning, and rearing. Physical features of dams, such as turbines and sluiceways, have resulted in increased mortality of both adults and juvenile salmon. Attempts to mitigate adverse impacts of these structures have to date met with limited success (NOAA 2014a).

Land use activities associated with logging, road construction, urban development, mining, agriculture, and recreation have also significantly altered quantity and quality of salmon habitat. Associated impacts of these activities include: alteration of streambanks and channel morphology; alteration of ambient stream water temperatures; degradation of water quality; reduction in available food supply; elimination of spawning and rearing habitat; fragmentation of available habitats; elimination of downstream recruitment of spawning gravels and large woody debris; removal of riparian vegetation resulting in increased stream bank erosion; and increased sedimentation input into spawning and rearing areas resulting in the loss of channel complexity, pool habitat, suitable gravel substrate, and large woody debris (NOAA 2014a). Studies indicate that in most western states, about 80 to 90 percent of the historic riparian habitat has been eliminated (NOAA 2014a).

As a result of these significant alterations to salmon habitat, there are currently five populations of salmon that have been listed as endangered under the Endagered Species Act, and 23 populations listed as threatened.

Another major environmental concern for aquatic species is the impact of nutrient runoff. Nutrient runoff, mostly from agriculture or waste, contributes to eutrophication and subsequent algae blooms. When algae die, they consume oxygen, leading the hypoxia, or “dead zones” that are depleted of oxygen and where other aquatic organisms cannot survive. Hypoxia is now a major issue in U.S. coastal waters and in the Great Lakes. A national assessment of U.S. water systems found that more than 50 percent of coastal systems have experienced hypoxia (Committee on Environment and Natural Resources 2010). Fisheries and related industries can suffer severe impacts as a result hypoxia. For example, one study estimates that the brown shrimp harvest was reduced by nearly 13 percent between 1999 and 2005 as a result of hypoxia in the Pamlico Sound of North Carolina. This equates to a total revenue loss of $1,240,000 (Huang et al. 2010).

In addition to contributing to eutrophic and hypoxic conditions that can lead to reduced abundance of wild foods, nutrient pollution has in some cases triggered harmful algal blooms. Harmful algal blooms consist of algal species that produce toxins that can kill fish, mammals and birds in addition to causing human illness. For example, harmful algal blooms can cause paralytic shellfish poisoning (PSP). If ingested, shellfish infected by PSP can be toxic or even fatal to humans. One report in 2000 estimated that U.S. economic losses as a result of harmful algal blooms were between $300 and $450 million in terms of impacts to tourism, public health, and commercial fisheries (Anderson et al. 2000). Recognizing the threat that nutrient pollution poses to aquatic ecosystems, federal agencies, including the U.S. National Oceanic and Atmospheric Administration (NOAA), EPA, USGS, and USDA, have contributed to addressing the problem through research, funding and outreach efforts. In the Chesapeake Bay, for instance, a consortium of state and federal agencies have worked for nearly two decades on establishing nutrient load reduction targets and promoting restoration activities in the Bay. Activities have included restricting nutrient discharges from point sources, technical assistance and funding for agricultural best management practices that reduce nutrient runoff, requiring stormwater runoff controls for new development, educational programs in schools, labeling of storm drains, and extensive wetland and oyster restoration activities.

Invasive species can also impact existing wild food stocks. According to data from the 1990s and 2000s, forty-four native species of fish are threatened or endangered by alien-invasive species. An additional 27 native species of native fish species are also negatively affected by introductions (Pimentel, Zuniga, & Morrison 2005). Invasive mussels, such as zebra mussels, also compete with native mussels, clams, and snails and reduce oxygen for fish and other aquatic species.

Overexploitation and overharvesting are other risks to wild food resources. The United States has witnessed the overexploitation and even extinction of some of its once abundant wild food species. The American bison, or buffalo, once numbered 25 to 30 million individuals. American bison were the primary food source for the Native Americans of the Great Plains who used every part of the bison for food, fuel, shelter, clothing and tools. The bison was also spiritually and culturally important to these peoples. Beginning in the mid-1800's, non-native hunters began to kill bison in great numbers primarily for their skins and tongues, which were considered a delicacy. The animals were hunted nearly to extinction by the 1880's with only a few hundred individuals remaining. Today bison have recovered to a steady population, and are even raised commercially as livestock, but are not abundant as they once were.

Box 5-1Atlantic Cod

The Atlantic Cod was once one of the largest commercial fisheries in New England, contributing significantly to the economy of the region. Even though the fishery was managed by the New England Fishery Management Council (established in 1976), it came close to collapse in the mid-1990's as a result of overfishing. In 1994 the Council made efforts to reduce fishing pressure in the Gulf of Maine and Georges Bank by one-third by controlling new vessels' entry into the fishery and limiting the amount of time spent fishing. The stock failed to recover as projected, however. After an assessment of the stock was conducted in 2012, it was determined that drastic cuts in the allowable catch limits were required to allow the stocks to rebuild. These equated to an 80 percent reduction in the quota for the Gulf of Maine and a 61 percent reduction for Georges Bank.

Photo Credit: NOAA

The passenger pigeon represents another cautionary tale; once the most abundant bird in North America, the passenger pigeon was an important source of protein for many of the early settlers. Commercial hunting of the species began in the mid-1800s and it was hunted to extinction in the wild by the late 1800s. The last known passenger pigeon died in a zoo in 1914. The fate of the passenger pigeon spurred legislation such as the Lacey Act of 1900 which prohibits the trade of plant and animals that have been illegally taken; the Weeks-McClean Act of 1913 which prevented the spring hunting and marketing of migratory birds as well as banning the importation of feathers for women's fashion; and the Migratory Bird Treaty Act of 1918 which replaced the Weeks-McClean Act and made it unlawful to hunt, capture or kill migratory birds covered under the law.

In addition to these federal actions, states began implementing hunting and fishing laws in the mid-1800's and early 1900's as many states began to see their big game and local fish stocks disappearing. Today, states heavily manage hunting and fishing through licenses and limits on hunting and fishing seasons. For certain fish and game species, there may be bag limits or catch quotas established to limit the absolute take.

Commercial fisheries are also regulated in the United States. The National Marine Fisheries Service (NMFS) was established in 1871 for the purpose of stewarding and managing marine resources and habitats. In 1976 Congress passed the Magnuson-Stevens Act, the law governing commercial fisheries. Under the Act, administered by the NMFS, eight domestic regional fisheries management councils help to develop and establish fisheries management plans. The Magnuson-Stevens Act yielded inconsistent results and in many cases did little to curb overfishing. The Atlantic cod fishery, for example, faced near collapse in 1994 as a result of overfishing (see box 5-1).

In 2006 an amendment to the Magnuson-Stevens Act was passed in an effort to end and prevent overfishing. The amendment put into place new provisions requiring the establishment of annual catch limits (ACL) for every managed commercial fishery (a total of 469 stocks) by 2012. In 2007, when these provisions were passed, 41 domestic stocks were on the overfishing list (NOAA 2014b). By 2014 only 10 of those stocks were still on the overfishing list. In addition to those stocks that were removed from the overfishing list, another 12 stocks have been added to the list since 2007, though half of these as a result of first-time stock assessments (NOAA 2014b). Once a fishery is determined to be overfished, a plan is put in place to restore stocks. A typical rebuilding plan will allow fishing to continue, but a reduced rate, until stocks are recovered. Forty-six stocks and stock complexes are currently under rebuilding plans, and of these, 13 are no longer overfished and continue to rebuild toward their target (NOAA 2014b).

Unlike the resources and management devoted to commercial fisheries and recreational hunting and fishing, information and management on use of many wild plants is absent or missing, making these more susceptible to overexploitation. For example, demand for edible forest products has spiked as a result of an increasing movement towards wild foods in the United States. Local food campaigns, such as the "From Farm-to-Fork" initiative in North Carolina, encourage the adoption of diets that incorporate locally sourced food (Curtis et al. 2010). In many locales this results in increased demand for wild-harvested edibles. In the case of ramps, a type of wild leek, the harvest of the roots and rhizomes to sustain the growing demand may have significant negative impacts on long-term population sustainability of this plant. Similar situations may be found with fiddlehead ferns, mushrooms, and berries. In general these plants are wild-harvested with little or no effort to manage them as natural resources and it is feared that the unregulated exploitation of these culinary resources may be having significant negative impacts on the biological diversity of U.S. forests.

Cases of overabundance stand in contrast those of overexploitation. One well documented case is that of deer overabundance. Deer populations in the eastern United States are nearly ten times that of the early 1700's. The removal of natural predators and controlled hunting have allowed deer populations to multiply and spread within rural and peri-urban environments. In Maryland, for example, it is estimated that there are an average of 30 deer per square mile, and sometimes as high as 95 deer per square mile (The Maryland Botanical Heritage Work Group 2014). Deer are correlated with negative impacts on the distribution and abundance of native bird and plant abundance (The Maryland Botanical Heritage Work Group 2014). Deer browse the forest understory, damaging seedlings and favoring native plants. This has the effect of disturbing natural forest generation, decreasing native plant abundance, and reducing competition for native plant species—which are not favored by deer—allowing them to out-compete native species.

5.2 Wild relatives for crop breeding

(This section is chapter 2 of the U.S. Country Report on the State of Plant Genetic Resources for Food and Agriculture, with some updates as denoted by italics.)

The *in situ* conservation of crop genetic resources, both wild and cultivated, is recognized as a valuable complementary strategy to *ex situ* seed banks and clonal genebanks (e.g., Bretting and

Duvick 1997) *and has served as the primary conservator of crop biodiversity. The USDA's National Plant Germplasm System (see http://www.ars-grin.gov/npgs/index.html) serves this function for the U. S. national and global agriculture*. Although few wild plants are used for food production in the U.S., there are numerous species native to the country that are progenitors, or wild relatives, of modern agriculturally important grain, fruit, nut, vegetable, forage, turf, and industrial crops, and also many naturalized wild crop relatives from the Old World (Khoury et al. 2013). These species occur as a part of natural ecosystems and as weeds in many agroecosystems on public and private lands throughout the country.

For the most part, *in situ* conservation of naturally occurring wild crop relatives occurs fortuitously on protected lands and wilderness areas. There are approximately 271 million hectares of forest and grassland in the U.S. managed by federal agencies. The federal agencies that manage the largest areas of land are the Department of the Interior (DOI)'s Bureau of Land Management (BLM) at 103.6 million hectares, Fish and Wildlife Service (FWS) at 38.9 million hectares, and National Park Service at 34.2 million hectares, and the Department of Agriculture's Forest Service (FS) at 77.6 million hectares.

The DOI's Bureau of Indian Affairs, as well as the Department of Defense, the Department of Energy, and the Tennessee Valley Authority also manage large parcels of protected land. Management of these lands involves the conservation of native plants, often focused on rare and endangered species. In addition, state and local governments in all 50 states manage thousands of protected areas, and, thus, are also active in monitoring and protecting rare plants.

Within the land managed by the FS, the U.S. Congress has set aside 14 million hectares of National Forest and National Grasslands as wilderness. The FS has also designated over 202 000 hectares as more than 430 Research Natural Areas (RNAs) that are permanently protected, in part for the purpose of maintaining biological diversity. The other federal agencies listed above are also responsible for managing wilderness tracts and many have established RNAs or their equivalents. Very few complete inventories of biodiversity have been conducted for these or other protected areas.

Recently, several private organizations have joined with the National Park Service to conduct inventories of all the species in several parks, under the auspices of the All-Taxa Biodiversity Initiative Alliance of Discover Life in America, Inc. (http://www.atbialliance.org/).

The Endangered Species Act of 1973 gave the FWS's Endangered Species Program the authority to designate plant and animal species as threatened or endangered, and to take appropriate steps to conserve habitat and protected species and reintroduce species to their native habitat. The Act also requires federal agencies to ensure that their activities do not jeopardize the existence of species of plants and animals designated as endangered or threatened or adversely modify designated critical habitat. Recovery plans have been developed for more than 600 of the designated flowering plant species. In addition to the species now listed as threatened or endangered, there are currently 130 plant species that are candidates for listing. Many states also confer some degree of protection to state-designated endangered and/or threatened plant species within their jurisdictions.

Based on data in the taxonomy section of the Germplasm Resources Information Network (GRIN) database, *Khoury et al. (2013) have identified as conservation priorities for the United States 821 plant taxa from 69 genera primarily related to major food crops, particularly the approximately 285 native taxa from 30 genera that are most closely related to such crops.* All of these threatened and endangered species merit protection because of their potential to provide unique genetic material for crop improvement. The emergence of an array of biotechnologies makes genes from wild crop relatives increasingly accessible for crop breeding and improvement; thus, their conservation is likely to be even more important in the future than previously anticipated.

It is important to note that although designation by the FWS or various states gives protection to endangered and threatened plant species, it is not designed to protect individual populations with unique traits nor does it protect rare cultigens. For agricultural purposes, unique traits at a population level are often of great value and may be specifically targeted for conservation.

In addition to governmental agencies, many individuals and private non-profit organizations are involved in conservation programs on privately owned land. The Nature Conservancy (TNC; see http://www.nature.org/) is a nonprofit conservation organization that manages approximately 1500 preserves in the U.S. and protects rare and endangered species and unique ecological communities, primarily through habitat preservation. Although these preserves were not specifically designed for the conservation of wild crop genetic resources, they serve this purpose in many cases. The databases of the State Natural Heritage Programs initiated by TNC contain information on the occurrences of rare species and their habitats in each state.

The Center for Plant Conservation (CPC; see http://www.centerforplantconservation.org/) is a network of 36 botanical institutions sharing a mission to conserve and restore rare native plants of the U.S. The CPC's National Collection of Endangered Plants contains samples of more than 700 of the country's most imperiled native plants. Live plant material is collected from nature and then maintained as seeds, rooted cuttings or mature plants by participating botanical institutions that study and hold the material in protective custody. After propagating the plants, these institutions provide seeds or vegetative propagules to federal and state agencies and private land-management organizations to assist in their efforts to restore imperiled plants in the wild.

Surveying and inventorying naturally occurring plant genetic resources, including crop-associated biodiversity, should be conducted on a continuing basis (see Heywood and Dulloo 2005). Although the scientific expertise to improve inventories and surveys currently exists throughout the various levels of government and the private sector, the greatest constraint to progress is sufficient funding to adequately support the number of scientifically trained personnel required to carry out the studies. In the future, the shrinking pool of field botanists being trained within the U.S. educational system will likely be an additional constraint.

<u>On-farm management and improvement of plant genetic resources for food and agriculture</u>
Although the number of Native American farmers in the U.S. is small, a few do still grow traditional varieties of crops and preserve the traditional farming practices of their ancestors. Many of the traditional landraces previously grown by native farmers are very rare or may be extinct. Several Native American tribes (for example, the Oneida in Wisconsin, the Pawnee in Nebraska, and the

Zuni in New Mexico) are striving to revive use of their traditional crop varieties, especially of maize, for cultural, religious and health reasons. In addition, other small farmers and hobbyists grow heritage varieties of diverse origins, including Native American varieties, more recent American varieties (for example, *Brassica oleracea* var. *viridis*, commonly known as collards), and Old World varieties brought by immigrants at some point since colonization.

The federal government does not provide incentives to farmers to conserve traditional cultivars, nor has it established a forum for stakeholders involved in on-farm conservation. However, some state and local governments and NGOs do support promotional and marketing programs that help incentivize specialized, local horticultural production. One prominent example is the Organic Seed Partnership/Northern Organic Vegetable Improvement Collaborative. During a ten-year period, organic farming organizations, several U.S. land-grant universities and the USDA/ARS National Plant Germplasm System (NPGS) site in Geneva, NY established a national network of organic vegetable breeders and producers who are conserving and improving heirloom vegetables for organic production (see http://www.plbr.cornell.edu/psi/OSP%20home.htm).

In addition to the NPGS, there are formal and informal groups and conservation networks in the United States that maintain traditional crop varieties. For example, Native Seeds/ SEARCH (see http://www.nativeseeds.org/) is a conservation organization in Arizona involved in the preservation of traditional crop varieties that originated in Native American and colonial communities of the Southwest U.S. and Northwest Mexico, and their wild relatives. This organization distributes seeds to approximately 4 000 farmers and gardeners each year, including Native Americans, and conducts an outreach program to promote the use of traditional crop varieties in indigenous communities. Another organization, the Seed Savers Exchange (see http://www.seedsavers.org/), with headquarters in Decorah, Iowa, is a nonprofit network of gardeners and farmers who maintain and distribute heirloom varieties of many vegetables and fruits.

Many seed companies offer heirloom varieties for sale, with some small companies focusing exclusively on them. No formal system exists in the U.S. to support local or small-scale seed production, but state and county extension personnel and extension-sponsored groups, such as Master Gardeners, are often available to assist. Unfortunately, budget reductions have curtailed the activities of many agricultural extension service offices around the country in recent years.

Farmers in the U.S. are rarely involved directly in the breeding of new cultivars. However, farmers do have opportunities to communicate their ideas and specific needs to public research and extension personnel and representatives of private seed companies, both individually and through discussions at local, state and regional grower meetings. Farmers also can cooperate with public and private breeding programs by participating in on-farm tests of advanced-generation breeding lines and newly released cultivars. They may also serve on boards of directors and advisory committees of private companies, producer cooperatives, universities, and agricultural experiment stations.

Restoring *crop genetic diversity and* agricultural systems after disaster

Crop agricultural disasters can take many forms. Epidemics of virulent diseases can sometimes cause such severe and widespread damage that they can be considered disastrous. To prepare for these recurrent epidemics, the United States established a National Plant Disease Recovery System (NPDRS) through the Homeland Security Presidential Directive Number 9 (HSPD-9) in 2004. The NPDRS seeks to ensure that the tools, infrastructure, communication networks, and capacity required to mitigate the impact of high-consequence plant disease outbreaks are available so that an acceptable level of crop production is maintained in the United States. USDA, the American Phytopathological Society, U.S. universities, and the U.S. seed industry have compiled or are compiling recovery plans for the most severe diseases threatening U.S. crop production. Crop genetic resources containing resistance genes are often critical elements of these plans. For more details, see http://www.ars.usda.gov/research/docs.htm?docid=14271.

Rangeland and forage resources have also been subjected to extensive damage from wildfires, especially in the western U.S., and the spread of invasive plants. To prepare for such disasters and their mitigation through the re-establishment of stable, native plant communities, in 2001, the DOI's BLM established the Seeds of Success (SOS) program (see http:// www.nps.gov/plants/sos/). SOS has developed a partnership of federal government agencies and non-governmental organizations that share the goal of conserving native plants and their communities. SOS supports collection of seed from native plant populations in the U.S. to increase the number of species, geographically appropriate material, and amount of seed available for use in stabilizing and rehabilitating land, and restoring it after disasters.

In situ conservation of wild crop relatives and wild plants for food production

As noted above, wild crop relatives, along with a few wild plant species directly harvested for food, occur on protected, publicly and privately owned lands. Managers, botanists and other employees working on these lands are aware of the importance of surveying to identify which species occur on these lands and of protecting them, but resources are often lacking to carry out these activities. However, many land managers are not aware of the special significance of wild crop relatives. In addition, it is typically difficult for federal, state and local officials, and private organizations concerned about plant conservation to communicate the importance of habitat preservation and *in situ* conservation of plant genetic resources to private land owners, but efforts are made to do so (*see Khoury et al. 2013*). Various conservation organizations, such as native plant societies, prairie networks, wildlife federations, and state natural heritage foundations, do develop outreach projects and collaborate closely with land owners to promote habitat preservation and restoration.

Overall, the greatest limitations to *in situ* conservation of plant genetic resources are identifying the locations of populations and protecting the plants' natural habitats (Khoury et al. 2013). Efforts need to be expanded to ensure that more areas are surveyed so that plant populations are identified and appropriate actions are taken to ensure their survival. If necessary, unprotected areas which harbor populations of plant genetic resources, especially those that are rare or have unique characteristics, should be secured and protected from habitat destruction. Threats to habitats include agricultural, residential, and commercial development, encroachment by invasive species, changes in fire and grazing regimens, climatic change, pesticide and herbicide use, overexploitation, and a variety of other factors. In addition to identifying the existence and locations of populations of important plant genetic resources, it is important to assess the genetic and breeding-system variation within and among populations to help ensure that diversity within species is maintained.

Perhaps the greatest need for improving *in situ* conservation of native crop genetic resources is improved communication within and among the large number of public and private organizations and individuals involved. Individuals at all levels within land-management agencies need to be alerted to the presence of wild crop genetic resources on their lands so that proper management practices are instituted to protect these resources. The information in government, TNC State Natural Heritage Program, and natural-history collection (herbarium) databases should be linked to facilitate conservation and monitoring of valuable genetic resources. The designation of areas of existing parks, wildlife refuges, or other protected areas known to contain wild relatives of crops, such as *Vaccinium*, *Carya*, and *Rubus* species, as *in situ* reserves, may help ensure their conservation. Also, the status of species or populations conserved in these areas needs to be carefully and periodically monitored.

State of the art

Currently, the *in situ* management of plant genetic resources in the United States primarily involves surveys and observations on public and private lands to confirm the existence of plants of various species, with documentation of findings in a database, and attempts to prevent damage or destruction of the plants' natural habitats. With the exception of a few species, little has been done to study the genetic diversity that exists between and within identified populations. The latter could provide important information about unique populations that merit special attention. This body of research has slowly expanded, but training of additional field botanists is required to sustain an adequate work force for assessing and protecting populations of wild crop relatives and other plants.

5.3 Organic

(Organic production both uses and contributes to biodiversity. It is included in Chapter 5 to conform with the outline for this report provided by the Commission on Genetic Resources for Food and Agriculture.)

Consumer demand for organically produced goods in the United States has grown markedly since the 1990s. Organic food sales reached $33 billion in 2014, according to estimates from the Nutrition Business Journal, (Nutrition Business Journal, 2015), and now account for over 4 percent of total U.S. food sales. Two of the top food retailers in the United States recently announced initiatives to expand the number of organic products they sell, which could further boost demand.

In the United States, fresh fruits and vegetables have been the top selling category of organically grown food since the organic food industry began marketing products over 30 years ago. According to the Nutrition Business Journal, retail sales of fruits and vegetables were over $13 billion in 2014, and accounted for 39 percent of U.S. organic food sales. The largest selling organic animal product category, dairy products, is the second-largest overall category, accounting for 15 percent of U.S. organic food sales.

Organic Certification and Acreage Growth in the United States

(Largely excerpted from McBride et al. 2015: 1-3)

Organic cropping systems rely on ecologically based practices, such as biological pest management and composting, and exclude most synthetic chemicals. Under organic cropping systems, the fundamental components and natural processes of ecosystems—such as soil organism activities, nutrient cycling, and species distribution and competition—are used as farm management tools (Greene and Kremen, 2003). For example, crops are rotated, pest prevention techniques are employed, animal manure and crop residues are recycled, and planting/harvesting dates are carefully managed. Major reasons for the popularity of organic farming are the low impact on the environment; the ability to farm without relying on a limited resource, synthetic nitrogen, which has negative environmental consequences such as nitrate pollution of groundwater and waterways; and the perception that organic food is more healthful. While economic concerns are important, they are not always the main reason farmers choose the organic approach.

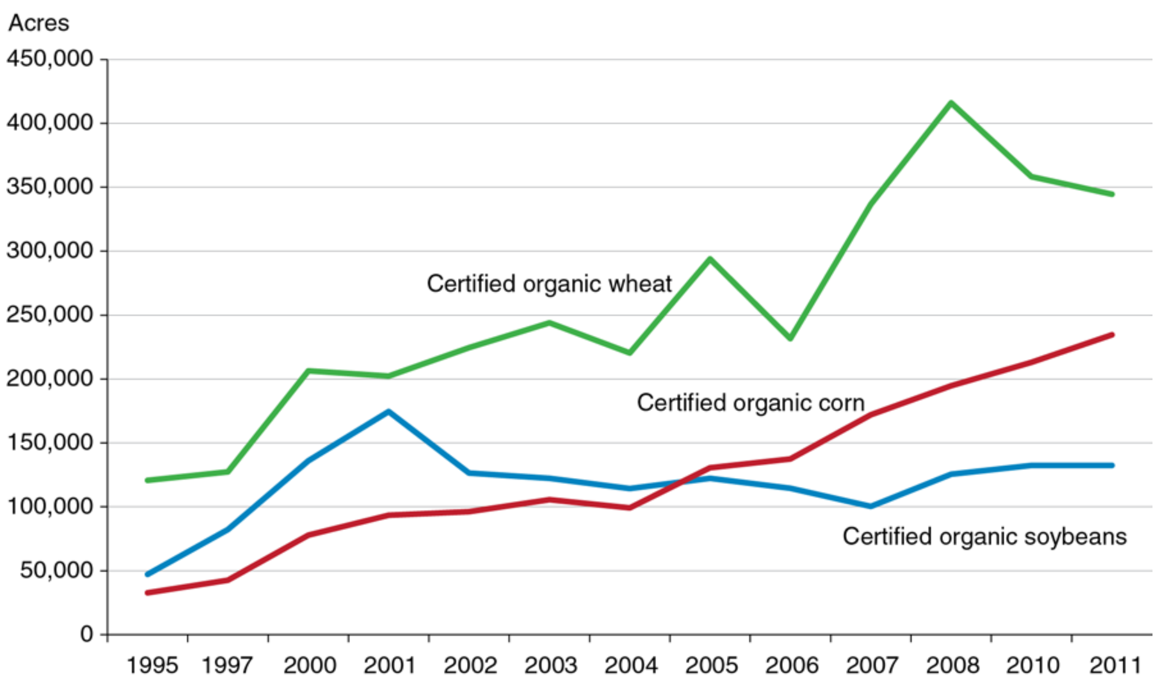
"Certified organic" is a labeling term that indicates that the food or other agricultural product has been produced through approved methods that integrate cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity (USDA AMS a). In the United States, the National Organic Program (NOP) is the Federal regulatory framework governing organic food and also is the name of the organization within the U.S. Department of Agriculture (USDA) responsible for administering and enforcing the regulatory framework. The Organic Foods Production Act of 1990 required that the USDA develop national standards for organic products. The NOP final rule was published in the *Federal Register* in December 2000 (Federal Register 2000).

The Organic Foods Production Act of 1990 "requires the Secretary of Agriculture to establish a National List of Allowed and Prohibited Substances, which identifies synthetic substances that may be used and the non-synthetic substances that cannot be used in organic production and handling operations." USDA promulgated regulations establishing the NOP standards and the USDA program in 2000. Certification is handled by State, nonprofit, and private agencies that have been approved by USDA. Under the NOP, farmers who wish to use the word "organic" in reference to their business and products must be certified organic.1 In addition to restrictions on which substances may be used to qualify for organic certification, certain production practices, such as crop rotations and pasture feeding requirements for ruminant animals, must be followed in order to maintain the organic certification status.

U.S. crop acres under USDA certified organic systems have grown rapidly since the NOP was implemented in 2002. Organic crop acres were nearly 2.5 times higher in 2011 than in 2002, as acreage increased from about 1.3 million to almost 3.1 million acres (USDA ERS 2013b). Fruit and vegetable growers and producers in other high-value, market-driven sectors have adopted organic management systems much more widely than producers of corn, soybeans, and other crops that are primarily used as feed grains. While over 10 percent of U.S. vegetable acreage for carrots and lettuce, for example, and about 5 percent of fruit acreage was under organic management in 2011, only 0.3 percent of U.S. corn and 0.2 percent of soybeans were grown under certified organic farming systems (Greene 2014).

Between 2002 and 2011, acreage for certified organic fruits and vegetables grew steadily, increasing from 137,000 acres in 2002 to 315,000 acres in 2011. In contrast, acreage for some major field crops increased substantially during this period, while growth was more modest or had stalled for others. Among the three major field crops (corn, soybeans and wheat) examined in a recent study from USDA's Economic Research Service (McBride et al. 2015) certified organic production of corn increased the most, from about 96,000 acres in 2002, to 234,000 acres in 2011 (Figure 5-1). Certified organic soybean acreage declined from a peak of 175,000 acres in 2001 to 100,000 acres in 2007, but rebounded to 132,000 acres in 2011. Organic wheat acreage was the largest in all years, starting from 225,000 acres in 2002and peaking at more than 400,000 acres in 2008, before falling to 345,000 acres in 2011.

Figure 5-1. U.S. Organic corn, wheat, and soybean acreage, 19995-2001[1]



[1] Organic crop acreage data were not available for 1996, 1998, 1999, and 2009.
Source: USDA, Economic Research Service.

Much of the increased organic corn production has been to support a rapidly growing organic dairy sector in which the number of certified organic milk cows increased nearly fourfold from about 67,000 in 2002 to nearly 255,000 in 2011 (USDA ERS 2013b). Higher prices for conventional corn, soybeans, and wheat since 2008 and somewhat slower demand growth for organic products during the economic recession, along with increasing imports of these crops, may have helped limit increases in U.S. organic acreage in more recent years (USDA NASS a).

To help defray the costs of organic certification incurred by U.S. producers and handlers under the National Organic Program, USDA provides financial support through several certification cost-share programs (USDA AMS b). Under these programs, USDA works with State agencies to reimburse certified organic operators for a portion of the costs the operators incur to obtain or maintain organic certification. In 2015, individual operators were eligible for reimbursement of 75 percent of their certification costs up to a maximum of $750 per category of certification. Total funding for these programs in 2015 was set at $11.2 million (USDA AMS a).[17]

Despite the rapidly increasing consumer demand for organic products in the United States, overall adoption of organic farming systems remains low, standing at less than 1 percent of total U.S. farmland acreage (USDA NASS b), largely due to the low levels of organic adoption among U.S. field crop producers for acreage-extensive crop production. The dearth of information about the relative costs and returns of organic and conventional production systems on commercial farms in the United States and the performance of farms that are choosing the organic approach, may play a role in the low levels of adoption among field crop producers.

<u>Potential Profitability in Organic Field Crop Production</u>
(From McBride et al. 2015: Summary)
This study of field crop production indicates a profit potential from organic systems that is primarily due to the significant price premiums paid for certified organic crops. Additional economic costs of organic versus conventional production were more than offset, on average, by higher returns from organic systems for corn and soybeans, although not for wheat. Other findings of this study:

- Organic field crop production was, on average, conducted on farms with less total acreage and less field crop acreage than conventional farms. Despite having fewer acres, producers of some organic field crops were less likely to work off-farm. These producers were also more likely to have attended college than conventional producers. Organic production more often occurred in northern States where pest pressures are less severe.

- Production practices used on organic and conventional field crop operations were quite different. Most conventional producers of corn and soybeans used genetically modified seed varieties not allowed for certified organic crop production. Most organic producers used mechanical practices, such as tillage and cultivating for weed control, while conventional producers rarely used a cultivator and relied mainly on chemical weed control. Organic corn and soybean producers more often rotated row crops with small grain and meadow crops and often included an idle year in the rotation. Conventional producers of these crops mainly used a rotation consisting of continuous row crops.

- Much of the experimental research on organic field crop production has found similar yields and lower per-acre costs from organic relative to conventional field crop production. However, the economic analysis used with the experimental research has primarily examined only operating or variable costs, excluding the economic costs of such resources as land, labor, and capital. Findings of this observational study of commercial organic and conventional field crop

[17] USDA also supports organic agriculture through the Environmental Quality Incentives Program (EQIP) Organic Initiative, which provides financial assistance to organic producers implementing conservation practices that address a broad array of resource concerns (USDA/Natural Resources Conservation Service (NRCS)).

production found lower yields and mostly higher per-acre total economic costs from organic systems.

- As in much of the economic analyses using experimental data, per-bushel operating costs of organic relative to conventional systems were similar in this study. However, the per-bushel economic costs of organic production were significantly higher because of the higher per-acre costs and lower yields.

<u>Organic Offers Biodiversity Benefits…</u>
One of the explicit objectives of USDA's national regulatory program on organic agriculture is "to promote ecological balance and conserve biodiversity" (USDA AMS 2000). Soil health is also addressed explicitly in the regulatory practice standards on soil fertility and crop nutrient management, where USDA requires organic producers to use practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion. In setting standards for organic livestock, USDA specifies that producers must accommodate an animal's natural nutritional and behavioral requirements, ensuring that dairy cows and other ruminants, for example, have access to pasture. USDA's organic livestock standards also incorporate requirements for living conditions, feed rations, and health care practices suitable to the needs of the particular species.

The preamble to the final rule establishing the NOP explains that the use of 'conserve' in the definition of organic production "establishes that the producer must initiate practices to support biodiversity and avoid, to the extent practicable, any activities that would diminish it. Compliance with the requirement to conserve biodiversity requires that a producer incorporate practices in his or her organic system plan that are beneficial to biodiversity on his or her operation."

In December 2014, USDA posted draft guidance on "Natural Resources and Biodiversity Conservation for Certified Organic Operations" (USDA 2014). This guidance, which was open for comments until the end of February 2015, clarifies the responsibilities of the organic operator to maintain or improve the natural resources of the operation as well as the responsibilities of the accredited certifying agent to verify operator compliance. The guidance applies to all certifiers, certified organic operations, and new applicants for certification. The Appendix to the guidance provides examples of practices that may maintain or improve natural resources and biodiversity.

Greene et al. (2009) provide an overview of the environmental benefits that can be attributed to organic production systems (pgs 14-15):

- *Reduced pesticide residues in water and food.* Organic production systems virtually eliminate synthetic pesticide use, and reducing pesticide use has been an ongoing U.S. public health goal as scientists continue to document its unintentional effects on non-target species, including humans.

- *Reduced nutrient pollution; improved soil tilth, soil organic matter, and productivity; and lower energy use.* A number of studies have documented these environmental improvements in comparing organic farming systems with conventional systems (USDA

Study Team on Organic Farming 1980; Smolik et al. 1993; Reganold et al. 2001; Mäder et al. 2002; Marriott and Wander 2006).

- *Carbon sequestration.* Soils in organic farming systems (which use cover crops, crop rotation, fallowing, and animal and green manures) may also sequester as much carbon as soils under other carbon sequestration strategies and could help reduce carbon levels in the atmosphere (Lal et al. 1998; Drinkwater et al. 1998, International Trade Centre-United Nations/World Trade Organization and FiBL 2007).

- *Enhanced biodiversity.* A number of studies have found that organic farming practices enhance the biodiversity found in organic fields compared with conventional fields (Mäder et al. 2002; Altieri 1999) and improve biodiversity in field margins (Soil Association 2000).

<u>…but Potentially Lowers Yields</u>
(From McBride et al. 2015: 12-13)
Organic and conventional crop yields reported in much of the published experimental research have been similar, but average organic yields in data from USDA's Agricultural Resource Management Survey (ARMS) for each crop were significantly lower than those of conventional production. Unit production costs were computed as per-acre costs divided by the yield per acre of each crop. The average yield for organic corn was 118 bushels per acre in 2010, compared with 161 bushels for conventional corn. Organic wheat producers had an average yield of 30 bushels per acre in 2009, compared with 44 bushels for conventional production. Average yields for organic soybean producers in 2006 were also significantly lower, 31 versus 47 bushels per acre for conventional production. This amounts to an average yield penalty for organic production on commercial farms of 27 percent for corn, 32 percent for wheat, and 34 percent for soybeans.[18]

Previous research, based primarily on long-term cropping system data, suggests that significant returns are possible from organic crop production, often the result of obtaining similar conventional and organic yields with lower organic production costs. This study finds organic crop yields to be much lower than those of conventional production. The yield differences estimated from ARMS are similar to those estimated from the 2011 Organic Production Survey (USDA NASS, 2012) relative to those from the 2011 Crop Production Report (USDA NASS b). These 2011 data show organic corn yields to be 41 bushels per acre less than conventional yields, organic wheat yields to be 9 bushels per acre less than conventional yields, and organic soybean yields to be 12 bushels per acre less than conventional yields (Figure 5-2). The organic/conventional yield differences estimated from the ARMS data are slightly larger at 43, 14, and 16 bushels per acre, respectively, for each crop.[19]

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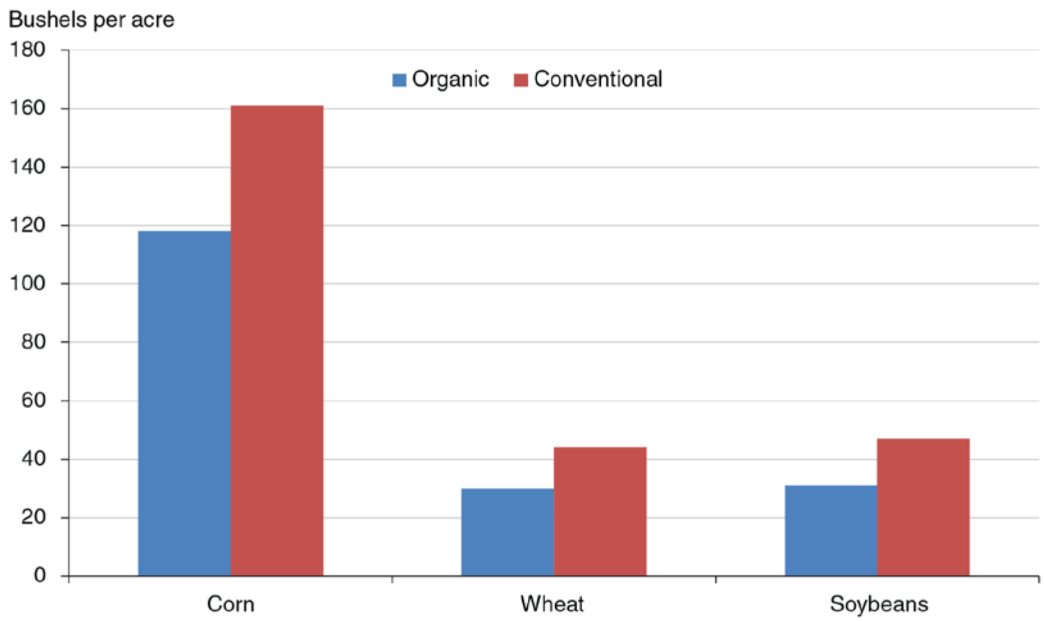
[18] The relationship between organic crop yields and experience with organic production was evaluated but was not statistically significant.
[19] Food-grade organic crops are generally lower yielding than feed-grade organic crops. Average organic food-grade soybean and wheat yields from the ARMS were not statistically different than average organic feed-grade soybean and wheat yields. Organic food-grade corn yields averaged about 25 bushels per acre less than organic feed-grade corn yields but food-grade corn comprised only about 10 percent of organic corn acreage. Food- and feed-grade organic acreage and production were not delineated in the 2011 Organic Production Survey.

As previously described, achieving yields was reported in the ARMS as one of the most difficult aspects of organic production. A reason for the yield differences measured with observational data may be the unique problems presented from implementing organic systems outside of the experimental setting, such as achieving effective weed control. Also, it is possible that the genetically modified conventional seed varieties that are commonly used for corn and soybean production are higher performing than standard organic seed varieties. Funding for organic seed development may have been less than for the genetically modified seed development over the two decades. Also, yields may also be lower in some organic field crop systems, such as for soybeans, partly because a high percentage of organic growers use lower yielding food-grade varieties, compared with conventional producers who mostly use feed-grade varieties (McBride and Greene 2009).

Figure 5-2. Organic and conventional corn, wheat, and soybean yields, 2001



Source: USDA, National Agricultural Statistics Service, 2011 Certified Organic Production Survey and Crop Production: 2011 Summary.

6. Interventions

The United States has a variety of policies and initiatives in place to specifically address threats to biodiversity for food and agriculture. Many of these programs work directly with private landowners to fund and promote sustainable management practices that benefit wildlife and improve soil and water quality. Benefits from these programs and policies are beginning to emerge, including the stabilization of net wetland acres, increased populations of wetland birds, and improvements in soil health. Significant efforts are also being made to improve habitat and mitigate impacts from agriculture on freshwater species and grassland birds. Finally, a recent White House initiative has called for significant efforts to confront the recent steep declines in pollinators.

U.S. policy mechanisms that directly or indirectly address biodiversity for food and agriculture can be grouped into five general categories (framework is adapted from Greenhalgh et al. 2014):

- Science research and data collection—policies that fund the type of scientific research and data collection that can help analyze the status of biodiversity, and identify and assess the threats and drivers of biodiversity change.

- Outreach and education—policies that help generate awareness, promote environmental education, and create data transparency.

- Regulatory approaches—policies that ban or restrict activities that pose a threat to biodiversity either directly or indirectly.

- Economic instruments—price-based instruments like taxes, fees and levies, subsidies and tax credits that can incentivize behaviors that are beneficial to preserving biodiversity. Also, market-based instruments such as ecolabelling and environmental markets that can create market demand for environmental outcomes.

- Land preservation and restoration—activities that protect or restore landscapes, for example, through the use of easements.

A selection of these policies and policy frameworks are discussed below.

6.1 Science research and data collection

As stated above, these include policies that fund the type of genetic resource conservation, scientific research and data collection that can help analyze the status of biodiversity, and identify and assess the threats and drivers of biodiversity change.

National Genetic Resources Program

In 1990, the U.S. Congress authorized establishment of a National Genetic Resources Program (NGRP). It is the NGRP's responsibility to acquire, characterize, preserve, document, and distribute to scientists, germplasm of all lifeforms important for food and agricultural production. The Genetic Resources Information Network (GRIN), which was developed and supported by the USDA Agricultural Research Service, provides germplasm information on plants, animals, microbes and invertebrates. See http://www.ars-grin.gov/ for further information. NGRP is composed of four sub-programs:

National Microbial Germplasm Program: The goal of this program is to ensure that the genetic diversity of agriculturally important microorganisms is maintained to enhance and increase agricultural efficiency and profitability. The program will collect, authenticate, and characterize potentially useful microbial germplasm; preserve microbial genetic diversity; and facilitate distribution and utilization of microbial germplasm for research and industry.

National Invertebrate Genetic Resource Program: Insects impact American agriculture both as destructive and beneficial organisms. Insect pests, parasites, predators, products, and pollinators are all economically important. It is critically important to distinguish between different species, races, stocks, strains, biotypes, and other genetic entities and to document their different interactions with agriculture and the environment. The specific goals of the National Invertebrate Genetic Resources Program include: Preservation of reference specimens; Maintenance of genetically important germplasm; Documentation of specific insect stocks; Management of databases; and Distribution of material to researchers and breeders.

National Animal Genetic Resources Program: This program's objectives are to strengthen the genetic diversity of the collection; improve cryopreservation procedures, provide potential users with comprehensive information about the collection through the GRIN database and enable greater efficiency in reconstituting populations. A multidisciplinary approach using quantitative and molecular genetics, reproductive biology, cryopreservation, awareness and evaluation of live animal populations, and information systems is needed to accomplish the objectives: Further develop and expand a scientifically based germplasm and DNA/tissue collection; Further develop the animal section of the GRIN network; Develop methods for population regeneration; Computationally determine approaches for population regeneration and management; and Improve cryopreservation methods for tissues.

National Plant Germplasm System: maintains more than 572,000 samples of more than 15,000 plant species (as of September 2015). The collection includes staple food and feed crops, horticultural crops, fruit and nut crops, industrial crops, ornamental crops, and forest tree crops. The collection is continually growing through acquisition of plant germplasm through international and domestic exchanges, and supporting international and domestic plant explorations. Samples are distributed free of charge and without restrictions each year to scientists and breeders, with an average over the past five years of more than 250,000 samples per year distributed, with about 80,000 of those samples going to facilities in more than 150 countries.

Natural Heritage Network

In the United States, a network of Natural Heritage Programs maintains and updates a database of information on rare and threatened species. The network databases identify species, natural communities, and ecosystems in need of protection at the local, regional, national, and global levels. For species, the network tracks the scientific name, distribution and population trends, habitat requirements, and ecological relationships. For natural communities, databases contain information on vegetation structure and composition, succession patterns, natural disturbances, and the distribution and rarity of specific community types throughout their geographic range. In addition, the network tracks the quality and condition of each occurrence of a community.

The Natural Heritage Network is a public-private partnership with state and federal governments that has existed for over 20 years. There are 85 Heritage units in the United States, covering all 50 states and the Navajo Nation. In most cases the Natural Heritage offices are funded by state government, though some are housed at universities or in the offices of the Nature Conservancy, a non-profit entity that initially developed the Natural Heritage Program.

The Natural Heritage Network uses a common methodology for classifying species. By using standardized methods and a data management system, Heritage Programs can exchange and analyze information across geographical and political boundaries. For example, several state Heritage Programs or CDCs can pool information on a region or an ecosystem that encompasses several programs' jurisdictions.

Breeding Bird Survey

The Breeding Bird Survey (BBS) is a long-term, large-scale, international avian monitoring program initiated in 1966 to track the status and trends of North American bird populations. The USGS Patuxent Wildlife Research Center and the Canadian Wildlife Service, National Wildlife Research Center jointly coordinate the BBS program. The BBS is an example of citizen science contributing to a broader and deeper understanding of biological trends.

Soil and Water Resource Conservation Act

The Soil and Water Resources Conservation Act (RCA) of 1997 provides natural resource strategic assessment and planning authority for the U.S. Department of Agriculture. The RCA calls for regular appraisals of the Nation's soil, water and related resources. These appraisals are meant to document the current status and trends of soil water and related natural resources as well as assess the ability of these resources to meet current and projected demands. The RCA also calls for an assessment of the effects of regulations, policies and programs on these resources. It also calls for a National Conservation Program to guide USDA assistance to landowners for conserving soil, water and related resources on private land. The National Conservation Program evaluates the Nation's natural resource problems; effectiveness of current authorities and programs; alternative methods for achieving conservation objectives; and costs and benefits of alternative conservation practices. An RCA Appraisal report is released every 5 years that provides the public with an overview of land use and the U.S. agricultural sector as well as the status, condition and trends of natural resources on private lands. Two additional reports complement

The National Resource Inventory (NRI)

The National Resource Inventory (NRI) has been collected every five years since 1977 to assess the state of the land. Through NRI data and other studies researchers are able to assess ongoing trends in conservation practices as a proxy for soil health, with a focus on soil carbon, soil erosion, adoption of reduced tillage practices, adoption of crop rotations, and adoption of cover crops.

The Conservation Effects Assessment Project (CEAP)

The Conservation Effects Assessment Project (CEAP) is a multi-agency effort to quantify the environmental effects of conservation practices and programs and develop the science base for managing the agricultural landscape for environmental quality. Assessments in CEAP are carried out at national, regional and watershed scales on cropland, grazing lands, wetlands and for wildlife. The three principal components of CEAP—the national assessments, the watershed assessment studies, and the bibliographies and literature reviews— contribute to building the science base for conservation. That process includes research, modeling, assessment, monitoring and data collection, outreach, and extension education. Focus is being given to translating CEAP science into practice.

The Forest and Rangelands Renewable Resources Planning Act

The Forest and Rangelands Renewable Resources Planning Act (RPA) of 1974 requires the Forest Service to prepare an assessment of renewable natural resources on the nation's forests and rangelands every 10 years. The RPA Assessment provides a snapshot of current U.S. forest and rangeland conditions and trends on all ownerships, identifies drivers of change, and projects conditions 50 years into the future. The most current assessment is for 2010 (U.S. Forest Service, 2012)

Natural Resources and Sustainable Agricultural Systems Research Program

Through the Natural Resources and Sustainable Agricultural Systems Research Program, USDA's Agricultural Research Service (ARS) supports researchers at 70 locations throughout the United States to develop the technologies and strategies needed to help farmers, ranchers, and other managers become effective stewards of the diverse agricultural ecosystems across the Nation. Programs include the Water Availability & Watershed Management; Climate Change, Soils and Emissions; Pasture, Forage & Rangeland Systems; Agricultural & Industrial Byproducts; Agricultural System Competitiveness & Sustainability; Bioenergy, Plant, Microbial & Insect Germplasm Conservation & Development.

Impact modeling and assessment

USDA supports modeling and assessment of impacts of agricultural practices on environmental outcomes through a number of integrated efforts, many of which are supported through USDA's Natural Resources Conservation Service (NRCS).

> *APEX Model.* The Agricultural Policy/Environmental eXtender (APEX) model addresses the impacts of management on environmental and production issues for whole farms and small watersheds. It is constructed to evaluate the wide array of management strategies applied to crop, pasture, and grazing lands and estimates long-term sustainability of land management with respect to erosion, economics, water supply, water quality, soil quality,

plant competition, weather and pests for crop land, grazing land and pasture land. Management capabilities simulated by APEX include: irrigation, surface and subsurface drainage, furrow diking, buffer strips, terraces, waterways, windbreaks, manure lagoons and water retention reservoirs, crop selection and rotation, input fate and application, grazing management, tillage timing and intensity, and harvest timing and methods. APEX can address strategic implications of global climate/CO_2 changes; confined animal feeding facilities, production systems for bioenergy, and other spin off applications. The model operates on a daily time step (some processes are simulated with hourly or less time steps), assimilating the changes in daily weather and with specific timing and application of management practices within the context of current knowledge of physical, biological and environmental processes. Simulations can examine one year or hundreds of years if necessary, and results can be summarized and examined daily, monthly, yearly or with multi-year analyses. APEX's unique feature is the ability to subdivide farms or fields by soils, landscape position, surface hydrology or management within a field or farm.

Nutrient Tracking Tool. The Nutrient Tracking Tool (NTT) is a user-friendly web-based computer program developed by the NRCS, USDA's Agricultural Research Service (ARS), and Colorado State University in collaboration with the Texas Institute of Applied Environmental Research staff at Tarleton State University. The tool estimates nitrogen, phosphorus, and sediment loss from fields managed under a variety of cropping patterns and management practices through its user-friendly linkage to the APEX model. NTT provides farmers, government officials, and other users with a fast and efficient method for estimating nitrogen and phosphorus credits for water quality trading, as well as other water quality, water quantity, and farm production impacts associated with conservation practices. The information obtained from the tool can help farmers determine the most cost-effective conservation practice alternatives for their individual operations and provide them with more advantageous options in a water quality credit trading program. NTT can also be used in evaluating conservation practice effectiveness outside of a water quality trading environment.

COMET-VR 2.0 and COMET-FARM. The CarbOn Management Evaluation Tool (COMET-VR 2.0) is an online tool developed through a partnership between NRCS and Colorado State University. COMET-VR 2.0 helps farmers and ranchers understand and assess impacts of changes in land management. It was initially designed as a simple and quick method to estimate management impacts on greenhouse gas (GHG) emissions pertaining to soil carbon sequestration, fuel use and fertilizer use. The most recent version of COMET-VR 2.0 estimates soil nitrous oxide emissions and gauges changes in biomass carbon stocks for agroforestry practices and perennial woody crops that include orchards and vineyards. COMET-VR 2.0 also provides producers and land managers additional agricultural management scenarios and a broad variety of nitrogen management options. The objective of COMET-FARM™, which is currently in beta status, is to create a whole farm and ranch carbon and greenhouse gas accounting and reporting system. It is intended to help users account for carbon flux and greenhouse gas emissions related to their farm and ranch management activities, and to help them explore the impacts of alternative management scenarios.

Rapid Carbon Assessment. A key component in addressing excess carbon dioxide in the atmosphere is understanding the dynamics of soil carbon. Soils act as either a sink or a source of atmospheric CO_2 depending on their land use and management. Soil properties such as texture, mineralogy, drainage class, and depth affect how much carbon can be retained and released. The Rapid Carbon Assessment project was developed to obtain statistically reliable estimates of current carbon stocks for soils of the U.S. The study takes into consideration ecosystem properties, soil type with respect to carbon retention, land cover, and agricultural management. Approximately 32,500 soil profiles have been sampled at 6,500 locations to develop the largest soil-carbon dataset in the world. Reports are currently available for total carbon stocks for cropland, Conservation Reserve Program, forest land, pasture, rangeland, and wetland. This data will be valuable for model calibration (e.g. COMET and APEX) and quantifying land management impacts on soil carbon for environmental markets.

Revised Universal Soil Loss Equation (RUSLE2). Released in 2003, the Revised Universal Soil Loss Equation 2 (RUSLE2) estimates soil loss from rill and interrill erosion caused by rainfall on cropland. RUSLE2 is used to predict the long-term average rate of rill and interrill erosion for several cropping systems and management-practice alternatives. It also considers specified soils, rainfall patterns, and topography. When predicted losses are compared with soil loss tolerances, RUSLE2 provides specific guidelines for effective erosion control.

Water Quality Index. NRCS has recently developed the Water Quality Index for Agricultural Runoff (WQIr,), a new web-based tool that assesses multiple aspects of water quality at the field scale. Water quality is quite complex and difficult to both assess and communicate in an aggregated way. The WQIr is a user-friendly tool that calculates an index score ranging from 0 (poor) to 10 (good) based on variables measuring field sensitivity (soil, slope and precipitation), nutrient management (timing, source, placement and form), tillage management (conventional to no-till operations), pesticide management, and irrigation management. The index is not crop specific, however, each of the input variables have weights that can be adjusted to reflect site specific data on county precipitation and field vegetation (including residue). As a result, the WQIr is able to combine nation-wide consistency with the ability to account for local variation in conservation effectiveness. The WQIr is currently being pilot tested in every state to help enumerate the outcomes for NRCS's National Water Quality Initiative.

Edge-of-Field Water Quality Monitoring. In 2012, NRCS developed and released two new conservation practice standards to support edge-of-field water quality monitoring. This provides quantitative measurements of the benefits of conservation practices for reducing nitrogen, phosphorus, and sediment losses from crop fields. The results will be used for calibrating and validating models of nutrient and sediment transport, as well as in assisting landowners employing adaptive management to achieve nutrient use efficiency, water quality, and other stewardship and production goals.

6.2 Outreach and Education

Outreach and education policies are those that help generate awareness, promote environmental education, and create data transparency.

USDA Conservation Technical Assistance Program

USDA's Natural Resources Conservation Service (NRCS) delivers conservation technical assistance through its voluntary Conservation Technical Assistance Program (CTA). CTA is available to any group or individual interested in conserving our natural resources and sustaining agricultural production. The CTA program functions through a national network of locally-based, professional conservationists located in nearly every county of the United States. This assistance can help landowners and land managers:

- Maintain and improve private lands and their management;
- Implement better land management technologies;
- Protect and improve water quality and quantity;
- Maintain and improve wildlife and fish habitat;
- Enhance recreational opportunities on their land;
- Maintain and improve the aesthetic character of private land;
- Explore opportunities to diversify agricultural operations; and
- Develop and apply sustainable agricultural systems.

Agriculture and Food Research Initiative (AFRI)

Through the Agriculture and food Research Initiative, USDA's National Institute of Food and Agriculture's (NIFA) funds research, education, and extension grants and integrated research, extension, and education that address key problems of National, regional, and multi-state importance in sustaining all components of agriculture, including farm efficiency and profitability, ranching, renewable energy, forestry (both urban and agroforestry), aquaculture, rural communities and entrepreneurship, human nutrition, food safety, biotechnology, and conventional breeding. Grants include education and extension that deliver science-based knowledge to people, allowing them to make informed practical decisions.

Sustainable Agriculture Research and Education (SARE)

Through the Sustainable Agriculture Research and Education program, NIFA supports research, education and professional development on sustainable agriculture, primarily through competitive grants that are offered through four regions under the direction of councils that include farmers and ranchers along with representatives from universities, government, agribusiness and nonprofit organizations. SARE's national outreach office publishes practical how-to books, bulletins and web resources for farmers, ranchers and educators. SARE supports the National Sustainable Agriculture Information Service, ATTRA.

Cooperative Extension System

Through the Cooperative Extension System, the United States' more than 100 land-grant colleges and universities provide vital, practical information to agricultural producers, small business owners, consumers, families, and young people. Through extension, land-grant institutions reach out to offer their resources to address public needs. By educating farmers on business operations and on modern agricultural science and technologies, extension contributes to the success of countless farms, ranches, and rural business. Further, these services improve the lives of consumers and families through nutrition education, food safety training, and youth leadership development. USDA'sNIFA supports both universities and local offices of the Cooperative Extension System to provide research-based information to its range of audiences. As the federal partner, NIFA plays a key role in the mission by distributing annual congressionally appropriated formula grants to supplement state and county funds.

6.3 Regulatory approaches

Regulatory approaches consist of policies that ban or restrict activities that pose a threat to biodiversity either directly or indirectly.

Endangered Species Act

The Endangered Species Act (ESA) was passed in 1973 with the purpose of protecting and facilitating the recovery of imperiled species and the ecosystems upon which they depend. It is administered by the U.S. Fish and Wildlife Service and the Commerce Department's National Marine Fisheries Service (NMFS). The FWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife such as whales and anadromons fish such as salmon (USFWS 2013).

Under the ESA, species may be listed as either endangered or threatened. "Endangered" means a species is in danger of extinction throughout all or a significant portion of its range. "Threatened" means a species is likely to become endangered within the foreseeable future. All species of plants and animals, except pest insects, are eligible for listing as endangered or threatened (USFWS 2013).

For activities on privately owned land such as farms and ranches, the primary direct impact of the ESA is through the law's prohibitions on taking of listed species. The word take means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Thus, such activities as applying pesticides to kill insects eaten frequently by an endangered bat species, or cutting down a tree that contains the nestlings of an endangered bird, would constitute a taking (CRS 2014).

Actions of some federal agencies may affect a variety of agricultural practices over a very wide area or a region and have the potential to affect many listed species. Perhaps the most widely known of such agency actions is the registration and use of pesticides. Under ESA, EPA is required to consult with FWS and/or NMFS on whether the use of a pesticide might jeopardize the continued existence of a listed species or adversely modify critical habitat. To mitigate harm, EPA might need to include restrictions on a pesticide label regarding its use (such as limiting total area, weather conditions, distance from a particular habitat type, etc.) (CRS 2014).

Migratory Bird Treaty Act

The Migratory Bird Treaty Act, which was first enacted in 1916 and implemented as a result of the Migratory Bird Treaty between the United States and Canada, makes it illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations. The Migratory Bird Treaty Act was one of the first federal environmental laws enacted in the United States. Today there over 800 species are currently on the list. The U.S. Fish and Wildlife Service is responsible for enforcing the law.

Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) is the primary law governing marine fisheries management in U.S. federal waters. First passed in 1976, the Magnuson-Stevens Act fosters long-term biological and economic sustainability of our nation's marine fisheries out to 200 nautical miles from shore. Key objectives of the Magnuson-Stevens Act are to:

- Prevent overfishing
- Rebuild overfished stocks
- Increase long-term economic and social benefits
- Ensure a safe and sustainable supply of seafood

Prior to the Magnuson-Stevens Act, waters beyond 12 nautical miles were international waters and fished by fleets from other countries. The 1976 law extended U.S. jurisdiction to 200 nautical miles and established eight regional fishery management councils (Councils) with representation from the coastal states and fishery stakeholders. The Councils' primary responsibility is development of fishery management plans (FMPs). These FMPs must comply with a number of conservation and management requirements, including the 10 National Standards—principles that promote sustainable fisheries management.

Congress has twice made significant revisions to the Magnuson-Stevens Act, first in 1996 with the passage of the Sustainable Fisheries Act, and in 2007 with the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act.

Under the Magnuson-Stevens Act, U.S. fisheries management is a transparent and robust process of science, management, innovation, and collaboration with the fishing industry. A scientific analysis of the abundance and composition of a fish stock (stock assessment) evaluates the stock to determine if the stock status is subject to overfishing or overfished. Stock assessments use the best information available, which may include data from fishery landings, scientific surveys, and biological and ecological studies. Stock assessments also provide NOAA Fisheries and the Councils with scientific data and analysis on which they can base and adjust management approaches to ensure sustainability.

As a result of the Magnuson-Stevens Act, the United States is ending and preventing overfishing in federally-managed fisheries, actively rebuilding stocks, and providing fishing opportunities and economic benefits for both commercial and recreational fishermen as well as fishing communities and shoreside businesses that support fishing and utilize fish products.

Clean Water Act

The goal of the Clean Water Act (CWA) is “to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters” (33 U.S.C §1251(a)). Sections 303(d) and 404 (described below) both have implications for biodiversity for food and agriculture. Section 303(d) pertains to improving impaired waters, which can pose a threat to species biodiversity, and section 404 includes provisions for wetlands.

Section 303(3) Impaired Waters

Under section 303(d) of the CWA, states are required to develop lists of impaired waters. The term "303(d) list" is short for the list of impaired and threatened waters (e.g., stream/river segments, lakes) that all states are required to submit for EPA approval during even-numbered years (EPA 2009)

The law requires that states establish a prioritized schedule for waters on the lists, and develop Total Maximum Daily Loads (TMDLs) for the identified waters based on the severity of the pollution and the sensitivity of the uses to be made of the waters, among other factors (40C.F.R. §130.7(b)(4)). A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards, and an allocation of that load among the various sources of the pollutant. States provide to EPA a long-term plan for completing TMDLs within 8 to 13 years from the first listing of the waterbody. EPA policy allows states to remove waterbodies from their 303(d) list after they have developed a TMDL or made other changes to correct water quality problems.

It is often the case that agricultural and other nonpoint source loads are given pollution reduction targets under a TMDL. While the CWA does not have regulatory authority over agriculture, there may be additional state or federal resources directed at agriculture with the goal of reducing targeted pollutants such as nitrogen, sediment or pesticides as the result of a TMDL. A TMDL may also be a driver for state-level regulations that can create regulator or voluntary incentives for implementation of best management practices. For example, in Maryland, a TMDL for the Chesapeake Bay was the driver behind the Maryland Revised Nutrient Management Act which requires farms to adopt a suite of nutrient management practices, including fencing along streams, fertilizer application set-backs along streams, and restrictions on winter nutrient applications. These types of activities are targeted at reducing nutrient runoff to streams and are beneficial to aquatic species, in addition to improving wildlife habitat along stream corridor as a result of fencing and setback requirements.

Section 404 Compensatory Wetland Mitigation

Section 404 of the Clean Water Act (CWA) establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports) and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States, unless the activity is exempt from Section 404 regulation (e.g. certain farming and forestry activities).Under Section 404, permitted activities must mitigate their impacts under the compensatory mitigation requirements. Compensatory mitigation refers to the restoration, establishment, enhancement, and/or preservation of wetlands, streams, or other aquatic resources conducted specifically for the purpose of offsetting authorized impacts to these resources.

In 2008, EPA and the U.S. Army Corps of Engineers jointly promulgated regulations revising and clarifying requirements regarding compensatory mitigation. According to these regulations, the fundamental objective of compensatory mitigation is to offset environmental losses resulting from unavoidable impacts to waters of the United States authorized by Clean Water Act Section 404 permits issued by the U.S. Army Corps of Engineers. Compensatory mitigation enters the analysis only after a proposed project has incorporated all appropriate and practicable means to first avoid and minimize adverse impacts to aquatic resources. Compensatory mitigation can occur through four methods: aquatic resource restoration, establishment, enhancement, or in certain circumstances, preservation.

6.4 Economic instruments

Economic instruments include price-based instruments like taxes, fees and levies, subsidies and tax credits that can incentivize behaviors that are beneficial to preserving biodiversity. Also, market-based instruments such as ecolabelling and environmental markets that can create market demand for environmental outcomes. The United States employs several economic instruments to incentivize activities that improve ecosystem health. The primary vehicle for this is the Farm Bill Conservation Title programs which provide incentives and cost-share for working agricultural and forestry lands to manage these resources sustainably. In addition, there are several market-based instruments, such as the USDA Organic Program, which seek to increase demand for food grown using environmentally beneficial practices.

Farm Bill Conservation Title programs

The U.S. Farm Bill Conservation Title creates several conservation programs that incentivize sustainable farming and grazing practices, fund retirement of ecologically sensitive lands, and provide technical assistance to producers. Studies have shown that the USDA conservation programs play an important role in restoration and protection of biodiversity. Some of these programs are described below.

Environmental Quality Incentive Program (EQIP)

EQIP provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation or improved or created wildlife habitat.

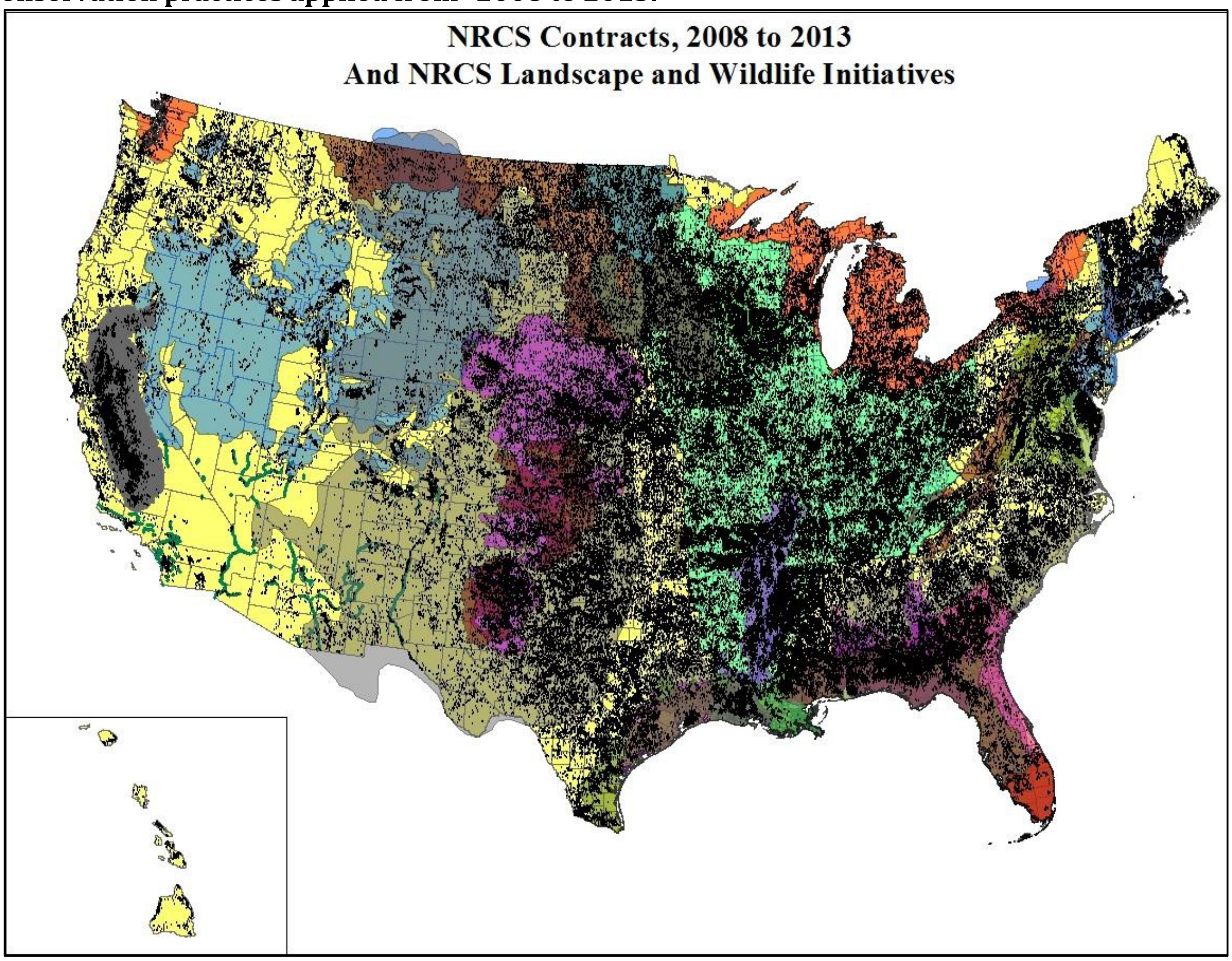
The Conservation Stewardship Program (CSP)

CSP helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resources concerns. Participants earn CSP payments for conservation performance—the higher the performance, the higher the payment.

Landscape Conservation Initiatives

NRCS uses landscape conservation initiatives to accelerate the results that can be achieved through voluntary conservation programs. All NRCS programs are designed to support farmers, ranchers, and foresters in improving the environment while maintaining or improving a vibrant agricultural sector. Most program delivery is driven primarily by grassroots input and local needs. Landscape conservation initiatives enhance the locally driven process to better address nationally and regionally important conservation goals that transcend localities. Examples of these goals include improving water quality in the Great Lakes (8 states), reducing the decline of the Ogallala Aquifer (8 states), and enhancing the habitat of keystone species like the greater sage grouse (11 states). Figure 6-1 illustrates current landscape and wildlife initiatives and NRCS-funded conservation practices.

Figure 6-1 NRCS wildlife and water initiatives ongoing in 2013 in color, dotted with NRCS conservation practices applied from 2008 to 2013.



Conservation Compliance

The purpose of conservation compliance is to reduce soil loss due to erosion; protect the nation's long-term ability to produce food and fiber; reduce sedimentation and improve water quality; and assist in preserving the values, acreage, and functions of the nation's wetlands.

Producers, and any affiliated individuals or entities who participate in most programs administered by the Farm Service Agency (FSA), the Natural Resources Conservation Service (NRCS), and the Risk Management Agency (RMA) are required to comply with the provisions of the Highly Erodible Land Conservation (HELC) and Wetland Conservation (WC) programs. These provisions aim to reduce soil loss on erosion-prone lands and to protect wetlands for the multiple benefits they provide. These provisions apply to all land that is considered highly erodible or a wetland, and that is owned or farmed by persons voluntarily participating in USDA programs, unless USDA determines an exemption applies. To comply with the HELC and WC provisions, producers must not:

- Plant or produce an agricultural commodity on highly erodible land without following an NRCS approved conservation plan or system;
- Plant or produce an agricultural commodity on a converted wetland; or
- Convert a wetland which makes the production of an agricultural commodity possible.

In addition, producers planning to conduct activities that may affect their HEL or WC compliance, for example removing fence rows, conducting drainage activities, or combining fields, must notify USDA. USDA will then provide highly erodible land or wetland technical evaluations and issue determinations if needed.

Non-compliance with these provisions may affect the following types of USDA program benefits:

- FSA loans and disaster assistance payments
- NRCS and FSA conservation program benefits
- Federal crop insurance premium subsidies

<u>Environmental Markets</u>

In the United States, environmental markets have emerged as a policy mechanism for providing flexibility and lowering the costs of meeting environmental regulations. Some of these regulated environmental markets are described below.

> *<u>Wetland and Stream Banking</u>*. Under Section 404 of the Clean Water Act, a permit is required before dredged or fill material may be discharged into U.S. waters, including wetlands. Permit applicants must show that steps have been taken to avoid impacts to wetlands, streams and other aquatic resources and that potential impacts have been minimized. In addition, they must show that compensation will be provided for all remaining unavoidable impacts.
>
> As a result of requirements to compensate for unavoidable impacts, wetland and stream mitigation banks have emerged in many parts of the country. A mitigation bank is a wetland, stream, or other aquatic resource area that has been restored, established, enhanced, or (in certain circumstances) preserved for the purpose of providing compensation for unavoidable impacts to aquatic resources permitted under Section 404 or a similar state or local wetland

regulation. These banks generate wetland or stream credits that can then be purchased and used to compensate for impacts elsewhere. A mitigation bank may be created when a government agency, corporation, nonprofit organization, or other entity undertakes these activities under a formal agreement with a regulatory agency. There are currently over 1800 mitigation banks in existence (USEPA 2014a).

Conservation Banking. Under the Endangered Species Act, activities that may result in incidental take of a protected species must be mitigated. Mitigation may include off-site protection of the listed species and its habitat and may take the form of purchasing credits in an approved conservation bank.

Conservation banks are permanently protected lands that contain natural resource values. These lands are conserved and permanently managed for species that are endangered, threatened, candidates for listing, or are otherwise species-at-risk. Conservation banks function to offset adverse impacts to these species that occurred elsewhere, sometimes referred to as off-site mitigation. In exchange for permanently protecting the land and managing it for these species, the U.S. Fish and Wildlife Service (FWS) approves a specified number of habitat or species credits that bank owners may sell. Developers or other project proponents who need to compensate for the unavoidable adverse impacts their projects have on species may purchase the credits from conservation bank owners to mitigate their impacts. Credits must be acquired by the permittee prior to commencement of actions authorized by an incidental take permit and intended to be mitigated by those credits (USFWS 2003).

Water Quality Trading. Water quality trading is an innovative approach to help achieve water quality goals more efficiently. Trading is based on the fact that sources in a watershed can face very different costs to control the same pollutant. Trading programs allow facilities facing higher pollution control costs to meet their regulatory obligations by purchasing environmentally equivalent (or superior) pollution reductions from another source at lower cost, thus achieving the same water quality improvement at lower overall cost. Water quality trading is only used for non-toxic and non-bioaccumulative pollutants such as nutrients and temperature.

Water quality trading can take many different forms, but the foundations of trading are that a water quality goal is established—either through a permit or other watershed goal—and that sources within the watershed have significantly different costs to achieve comparable levels of pollution control. The driver for trading has generally been provisions under the Clean Water Act. For example, in the Chesapeake Bay a Total Maximum Daily Load is in place for nitrogen and Phosphorus. As a result, the states in the Chesapeake Bay (Virginia, Maryland and Pennsylvania) have begun issuing more stringent nutrient discharge limits in permits for wastewater treatment plants. In addition, Virginia has also limited the amount of phosphorus discharge allowable from new construction sites. These states each implemented trading programs that allow regulated sources the flexibility of purchasing nutrient credits to meet their permit limits at lower cost. Credits can be generated from other regulated sources that reduce pollution below their permitted loads, or from other sources such as agriculture which may undertake additional activities to reduce pollution at lower cost. There are currently approximately 15 active water quality trading programs in the United States.

6.5 Land preservation and restoration

The U.S. government helps to preserve and restore both public and private lands. Private lands are generally protected for habitat values through voluntary easement programs. The U.S. government also manages millions of acres of forests and grasslands in part or in whole for the purpose of wildlife conservation. See below for specific programs established for land preservation and restoration.

The Agricultural Conservation Easement Program (ACEP)

ACEP provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits. Under the Agricultural Land Easements component, NRCS helps Indian tribes, state and local governments and non-governmental organizations protect working agricultural lands and limit non-agricultural uses of the land. Under the Wetlands Reserve Easements component, NRCS helps to restore, protect and enhance enrolled wetlands. Studies of wildlife establishment on lands enrolled in the Wetlands Reserve Easement component showed favorable responses among a number of bird and amphibian species (Rewa 2015). Region-specific studies reveal a similar picture. For example, a study of southern Oregon/Northeastern California found that there were enough existing easements in the Wetland Reserve Easement component to meet a fifth of the energetic needs for spring-migrating dabbling ducks (USDA NRCS 2013).

Conservation Reserve Program (CRP)

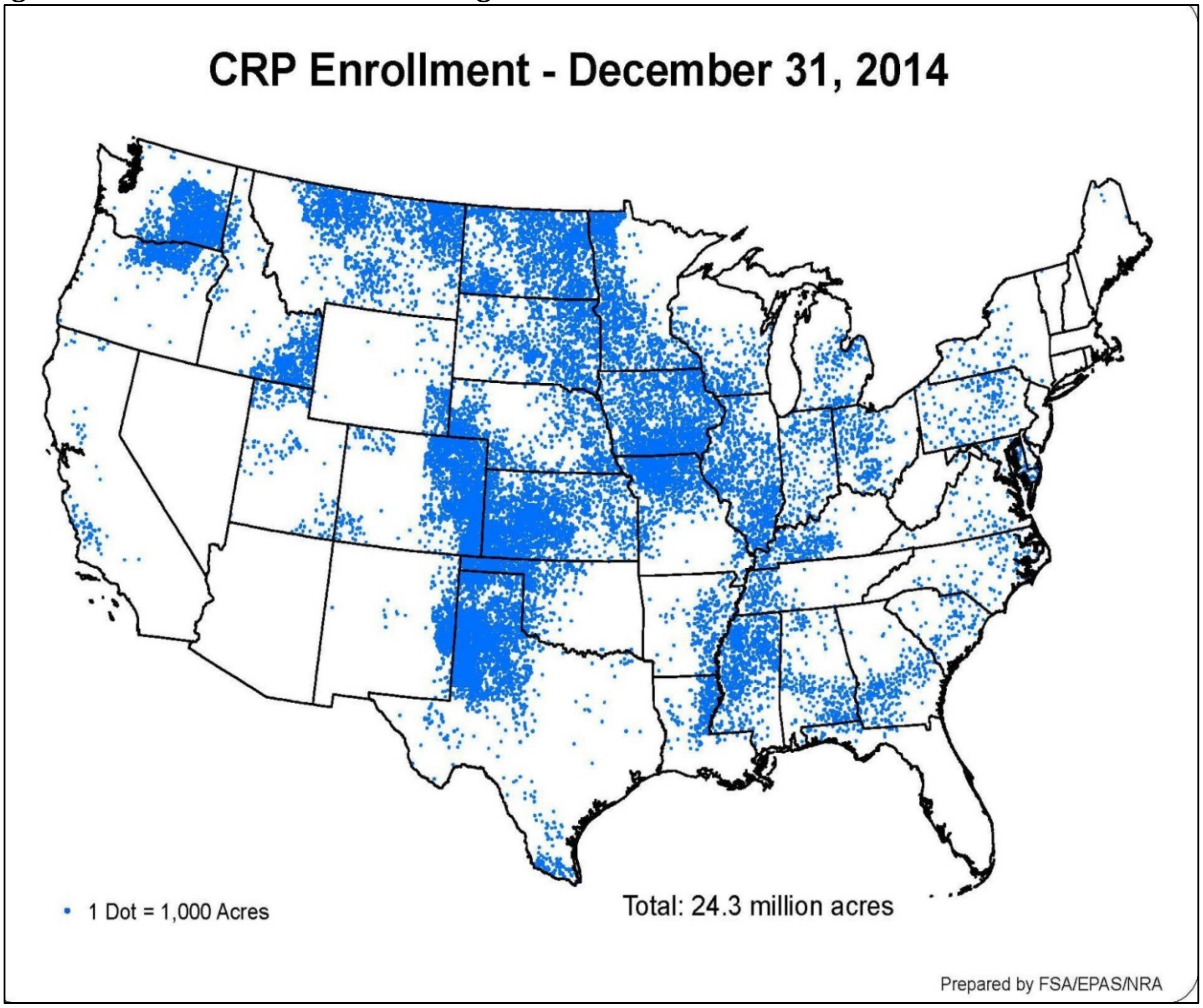
Established in 1985, CRP is a land conservation program administered by the USDA Farm Service Agency (FSA). In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality. Contracts for land enrolled in CRP are 10-15 years in length. There are currently 24.3 million acres enrolled in CRP (Figure 6-18). The long-term goal of the program is to re-establish valuable land cover to help improve water quality, prevent soil erosion, and reduce loss of wildlife habitat. There are multiple CRP initiatives targeting wildlife and biodiversity. These include the State Acres for Wildlife Enhancement, and the Upland Bird Buffer, Flood Plain Wetlands, Duck Nesting, Pollinator Habitat, and Honey Bee Initiatives.

Studies have shown that lands enrolled in CRP provide benefits to a number of bird species studied such as lark bunting, western meadowlark, horned lark, Savannah sparrow, bobolink, and many others including waterfowl (Johnson 2005). As one study showed, restored grasslands on CRP lands attracted grassland bird species almost immediately and they continued to return to the sites (Gill 2006).

The Healthy Forests Reserve Program (HFRP)

HFRP helps landowners restore, enhance and protect forestland resources on private lands through easements and financial assistance. Through HRFP, landowners promote the recovery of endangered or threatened species, improve plant and animal biodiversity and enhance carbon sequestration.

Figure 6-18 Conservation Reserve Program contracts as of December 2014



Source: FSA, USDA, 2015

National Wildlife Refuge System

The National Wildlife Refuge System is a system of public lands and waters set aside for the purpose of conserving wildlife. From the earliest years national wildlife refuges have played a major role in the evolution of resource conservation in the United States. The National Wildlife Refuge System now comprises more than 520 units in all 50 states, American Samoa, Puerto Rico, the Virgin Islands, the Johnson Atoll, Midway Atoll and several other Pacific Islands. Refuges encompass over 93 million acres of valuable wildlife habitat. Included in this total are nearly l.9 million acres of wetlands in the prairie pothole region of the north-central United States. These wetlands are known as "waterfowl production areas," and have Federal protection through fee acquisition or easements. This vital habitat, together with the wetlands of the Canadian prairies and Alaska, provides the key production areas where the bulk of North America's waterfowl nest and rear their young.

National Forest System

The National Forest System is comprised of approximately 191 million acres of federal lands; the system includes 155 national forests and 19 national grasslands across 41 states. These federal lands are managed to serve many uses including timber production, grazing, watershed protection, recreation, and habitat for wildlife.

National Park System

The world's first national park was Yellowstone National Park, established in 1872 by an act of Congress. The establishment of the park was to prevent private development and settlement of the land and preserve it for the enjoyment of the American people. The National Park System today comprises 376 areas covering more than 83 million acres in 49 States, the District of Columbia, American Samoa, Guam, Puerto Rico, Saipan, and the Virgin Islands. Congress created the National Park Service in 1916 through the National Park Service Organic Act. The mission of the National Park Service is to preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations. National Parks help preserve biodiversity by protecting large areas from development and exploitation. The National Park Service also is working to preserve biodiversity more broadly by restoring ecosystems, controlling invasive species, practicing integrated pest management, and through other conservation measures.

Wilderness Act of 1964

The Wilderness Act, signed into law in 1964, created the National Wilderness Preservation System and recognized wilderness as "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." The Act further defined wilderness as "an area of undeveloped Federal land retaining its primeval character and influence without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions . . . ." (For the complete definition of wilderness, see Section 2(c) of the Wilderness Act.) Congress has now designated more than 106 million acres of federal public lands as wilderness: this includes 44 million of these acres in national parks and another 20.6 million acres in wildlife refuges.

7. Data Gaps and Research Needs

The United States has begun to amass trend data to assess the state of biodiversity for food and agriculture, though many gaps remain. While there are significant amounts of information collected by the Heritage Network of species population trends, as well as significant amounts of national-level data that can serve as indicators for ecosystem health (e.g. wetland extent, soil erosion, etc.), these data can be improved. For example, an indicator for the "status of animal species in farmland areas" was recognized as a data gap in the 2008 "State of the Nation's Ecosystems" report released by the Heinz Center. New and varied indicators of soil health would provide better measurements of biodiversity.

Additional knowledge gaps exist in the holistic assessment of the impacts of agricultural management practices on the environment and biodiversity. For example, data about the number of crops constituting certain rotations, and the amount of genetic diversity in the current "standing crop" or "on the farm" are essentially lacking.

Further investment in research on the impacts of agricultural production will enhance our ability to allocate resources and mitigation activities in order to best preserve and enhance biodiversity for food and agriculture. Further investment in monitoring and the compilation of trend data will strengthen our ability to gauge our success. Findings from this report will help target future investment and research.

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